EXHIBIT A

EXHIBIT
108

FIRE
DYNAMICS ANALYSTS

Preliminary Summary Report

September 9, 2024

Mr. Eugene LaFlamme
McCoy Leavitt Laskey LLC
N19 W24200 Riverwood Drive
Suite 125
Waukesha, WI 53188
(262)522-7000

Re:	Stephanie Wadsworth & Matthew Wadsworth v. Walmart, Inc & Jetson Electric Bikes LLC
Location of Loss:	1620 HWY 374, Green River, WY
Date of Loss:	Tuesday, February 1, 2022
FDA File Number:	24033
Date Received:	April 11, 2024
Service Requested:	Case Review/ Computer Fire Modeling and Fire Dynamics Review
Lead Analysts:	Gregory E. Gorbett Ph. D., IAAI-CFI, CFEI, CFII, CFPS, CVFI

EXHIBIT D

Table of Contents

The following is a preliminary summary report of the review to date. It is designed to present a summary of the investigation's facts and list the basic findings, conclusions, and opinions based on the information available to the date of this report. It is expected that if additional, more detailed information becomes available, it will be added to this analysis.

This report is not intended to list and describe each fact upon which the findings and conclusions are based. However, each finding, conclusion, and opinion listed herein is based upon the information obtained during the investigation to date, research conducted by Fire Dynamics Analysts, review of file materials, and the investigator's knowledge, training, education, experience, and expertise.

1.0 BACKGROUND

On April 11, 2024, Mr. Eugene LaFlamme of McCoy Leavitt and Laskey retained Dr. Greg Gorbett of Fire Dynamics Analysts, LLC, to conduct an independent analysis of a fire occurring on February 1, 2022, at 1620 HWY 374, Green River, WY. The fire was first reported to '911' at approximately 4:27 AM on February 1, 2022.[1]

1.1 MATERIALS REVIEWED

Materials supplied and reviewed in the investigation of the incident to date include:

- Complaint – (received 3/25/24)
- Matterport scans – (received 5/8/24)
- AEI Photos & Notes – (received 5/8/24)
- Depo Transcripts & Exhibits (Apostolope, Erdmann, Hansen, Kaumo, Merrill, Pasborg, Ribordy, Robinson, Sheaman, Wadsworth, M & Wadsworth, S.) – (received 4/22/24)
- Filas Photos, xrays – (received 4/22/24)
- Hoverboard xray – matterport scan CT – (received 4/22/24)
- Sweetwater County Sheriff Photos, videos, etc. – (received 4/22/24)
- FTIR scan of Shed – (received 5/23/24)
- Kamille Wadsworth 5/20/24 depo transcript – (received 6/13/24)
- Layne Wadsworth 5/20/24 depo transcript – (received 6/13/24)
- Gunner Wadsworth 5/20/24 depo transcript – (received 6/13/24)
- Weston Wadsworth 5/20/24 depo transcript – (received 6/13/24)
- City of Green River file – (received 7/19/24)
- Deposition Exhibits – (received 7/19/24)
    - Sweetwater County Sheriff Photos, Videos, interview and report
    - Sweetwater Fire District #1 Report

[1] Green River FD Incident Report, p. 3

- Sweetwater County Sheriff Report
- Sweetwater Combined Comm Center CAD detailed report
- Sweetwater CAD 911 audio
- Green River Fire Dept Report
- Depo Transcripts of: Apostolope, JP; Hansen, John; Kaumo, Richard; Merrill, Ashley; Ribordy, Jake; Erdmann, Larry; Pasborg, Ryan; Robinson, Bill; Sheaman, Jeff; Wadsworth, Matthew; Wadsworth, Stephanie; Kremers, Coryn; Husain, Sam

- Jetson Doc Production 6.14.24 Bates JETSON 0248-1009 – (received 7/31/24)
- Jetson Answers to Pltf IRROGs– (received 7/31/24)
- Jetson Resp to Pltf 1st RFP – (received 7/31/24)
- Jetson Resp to Pltf RFA– (received 7/31/24)
- Walmart Resp to Pltf 1st RPD– (received 7/31/24)
- Michael Schulz Report– (received 7/15/24)
- Derek King Report– (received 7/15/24)
- Michael Schulz Expert File – (received 8/16/24)
- Derek King Expert File – (received 8/14/24)
- Deposition transcripts and Exhibits of Plaintiff Expert Derek King – (received 8/28/24)

1.2 QUALIFICATIONS OF EXPERT – GREGORY E. GORBETT

Dr. Gregory E. Gorbett is a full-time Professor at Eastern Kentucky University teaching in the Fire Protection and Safety Engineering Technology Program. Dr. Gorbett is also a professional Fire and Explosion Analyst. He holds National Board Certification as a Certified Fire and Explosion Investigator (CFEI), International Association of Arson Investigators Certification as a Certified Fire Investigator (CFI), as well as certification as a Certified Fire Protection Specialist (CFPS) through the National Fire Protection Association. CFEI status deals with accurately listing a fire or explosion's origin, cause, and responsibility. CFPS status deals with fire protection and fire safety, as well as knowledge of fire safety codes and standards.

Dr. Gorbett holds two Bachelor of Science degrees, including a cum laude Bachelor of Science degree in Forensic Science and a Bachelor of Science degree in Fire Science from the University of Maryland. He also holds two Master of Science degrees, one in Executive Fire Service Leadership and the other in Fire Protection Engineering. He also has a PhD in Fire Protection Engineering. He is a member of the National Fire Protection Association's Technical Committee of the Standard for Fire Investigator Professional Qualifications (NFPA 1033, between 2004-2014, 2016-present) and was a member of the National Fire Protection Association's Technical Committee on Fire and Explosion Investigations (NFPA 921) between 2016-2018. The Technical Committee on Fire Investigator Professional Qualifications writes National Fire Code, NFPA 1033 *Standard for Professional Qualifications for Fire Investigator*. The Technical Committee on Fire

Investigations writes the National Fire Code, NFPA 921 - *Guide for Fire and Explosion Investigations.* He served as the Chairman of the Executive Board of the NFPA Fire Science and Technology Educator's Section, served on the Board of Directors for the National Association of Fire Investigators (2003-2017), served as the Vice-Chair of the *Fire and Arson Investigator* Journal of the International Association of Arson Investigators (2012-2019), and was the Executive Secretary on the Crime Scene/Death Investigation Scientific Area Committee's (SAC's) Fire and Explosion Investigations Subcommittee within the Organization of Scientific Area Committees (OSAC) within the National Institute of Standards and Technology (NIST).

Enclosed with this report is a copy of Dr. Gorbett's current curriculum vitae (CV).

2.0 FIRE DYNAMICS ANALYSTS STANDARD OF CARE POLICY

This analysis has been conducted according to the precepts of National Fire Code NFPA 921, *Guide for Fire and Explosion Investigations,* and the current accepted principles of fire incident investigation and analysis as espoused by the National Fire Protection Association and the National Association of Fire Investigators.

Since its inception in 1992, NFPA 921 has represented the current state-of-the-art and industry standard of care for fire and explosion investigations. It is the only truly peer-reviewed consensus document in the field. The National Association of Fire Investigators and many courts in Canada and the United States have recognized it as the minimum standard of care for fire investigation. Fire Dynamics Analysts, LLC adheres to the standard of care outlined in NFPA 921 and other recognized industry treatises.

2.1 METHODOLOGY

The investigation and analysis of any fire-related incident are complex scientific endeavors. Therefore, the methodology of such an endeavor must include a comprehensive, objective, and accurate compilation and analysis of the available data.

The fire investigation and analysis methodology can only be accomplished through applying and using a systematic approach, which will foster the appropriate compilation and analysis of the available data. During the analysis, the scientific method was employed. The scientific method is

a systematic approach to problem-solving commonly utilized in all the physical sciences and espoused by the National Fire Protection Association for conducting professional fire and explosion investigations and analyses. The application and use of the scientific method ensured that this investigation and analysis was conducted according to the recognized and accepted standards and practices of fire and explosion investigation and analysis profession as those standards and practices that are documented in the National Fire Code, NFPA 921, *Guide for Fire and Explosion Investigations.*

2.2 Applicable Codes and Standards

Among the codes, standards, and laws applicable to the investigation of this incident are:

NFPA National Fire Codes

NFPA 921 – 2024 *Guide for Fire and Explosion Investigations*
NFPA 1033–2024 *Standard for Professional Qualifications for Fire Investigator*

National Institute of Standards and Technology (NIST)

NIST Special Publication 1019-6 – *Fire Dynamics Simulator (Version 6) User's Guide- http://dx.doi.org/10.6028/NIST.SP.1019*
NIST Special Publication 1018-3 – *Fire Dynamics Simulator (Version 6) Technical Reference Guide,* Volume 3: Validation
NIST Special Publication 1018-2 – *Fire Dynamics Simulator (Version 6) Technical Reference Guide,* Volume 2: Verification
NIST Special Publication 1018-1 – *Fire Dynamics Simulator (Version 6) Technical Reference Guide,* Volume 1: Mathematical Model

Nuclear Regulatory Commission (NRC)

NRC: NUREG-1824 – *Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications.*

American Society for Testing and Materials

ASTM E603, *Standard Guide for Room Fire Experiments*
ASTM E1355, *Standard Guide for Evaluating the Predictive Capability of Deterministic Fire Models*
ASTM E1472, *Standard Guide for Documenting Computer Software for Fire Models*
ASTM E1591, *Standard Guide for Obtaining Data for Fire Growth Models*
ASTM E1895, *Standard Guide for Determining Uses and Limitations of Deterministic Fire Models*
ASTM E678, *Standard Practice for Evaluation of Technical Data*
ASTM E620, *Standard Practice for Reporting Opinions of Technical Experts*

Society of Fire Protection Engineers

SFPE -Guidelines for Substantiating a Fire Model for a Given Application (2010)

3.0 DATA COLLECTED

3.1 GEOMETRY AND LAYOUT OF THE STRUCTURE

The structure was located on Highway 374, between I-80 and HWY 374, in Green River, WY (Figure 1). The front of the structure faced west towards HWY 374. The structure's electrical service entrance entered through the east side's center.

Figure 1: Google Earth view of I-80 and HWY374 in Green River, WY (Note: red pin is 1620 HWY 374, Green River, WY)

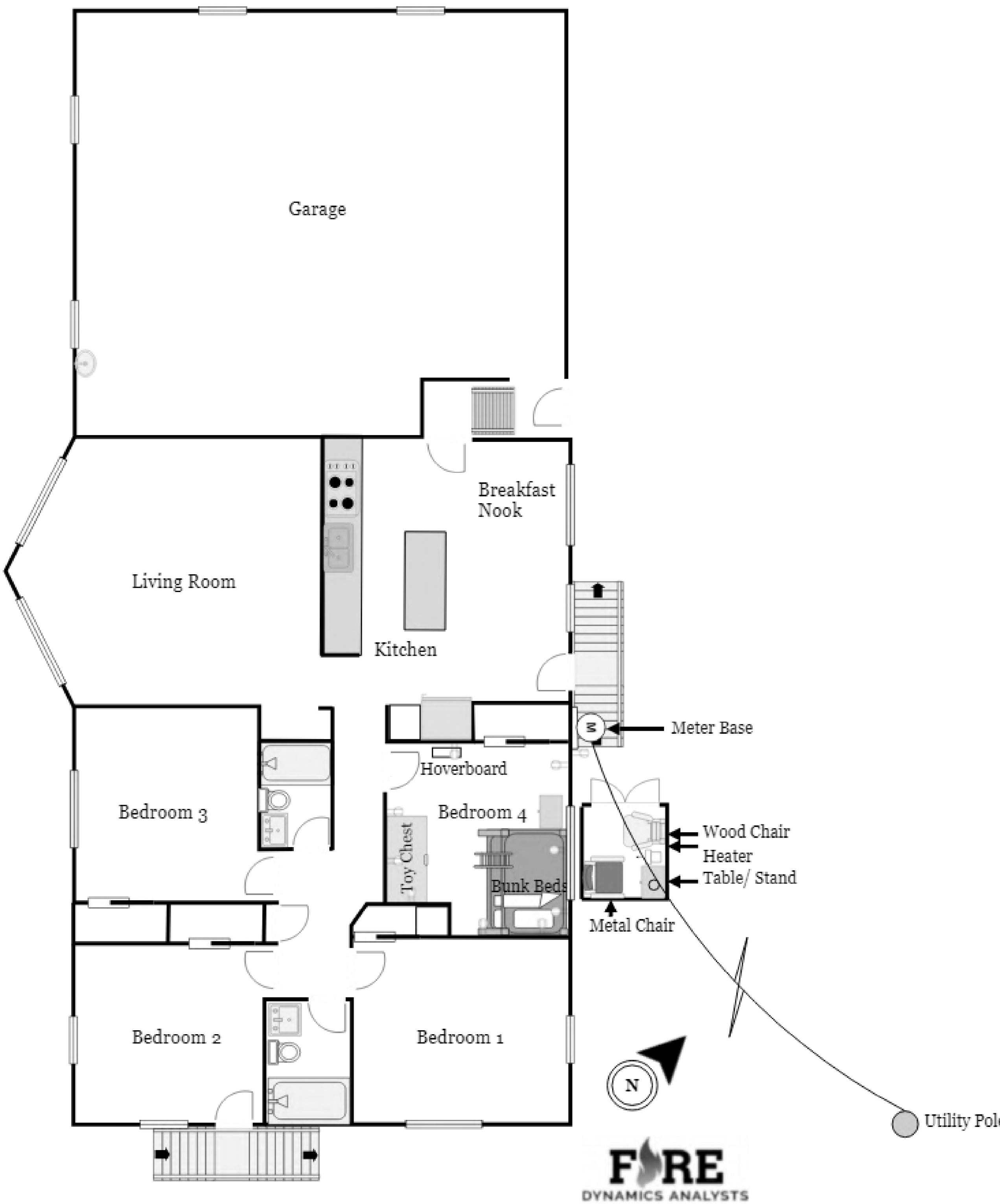

Figure 2: Diagram of the first floor at 1620 HWY 374, Green River, WY

The one-story structure was a single-family residence built on a full basement with an attached garage (Figure 2). The upper half of the structure's exterior elevation of the structure was covered with siding, and the lower half was lined with stone. The interior walls were lined with wood paneling with wooden 2x4 studs serving as the frame. The house's first floor consisted of a living room, kitchen, and breakfast nook along the north half of the house and four bedrooms extending off of a hallway along the south half (Figure 2). An Eagle 4-drum polyethylene storage building intended to store up to four 55-gallon drums was located along the east exterior side of the residence under the window of bedroom #4 (Figure 3). The family was using it as a shed for smoking purposes (Figures 2-3).

Figure 3: Eagle 4-Drum Polyethylene Outdoor Storage Shed

Ventilation openings (e.g., doors and windows) are essential to evaluating fire dynamics within a structure and govern much of the physics of fire growth and spread during the fire. Each room's dimensions and ventilation openings were captured through the Matterport 3D scan and Matterport building information modeling (BIM) file (Figure 4).

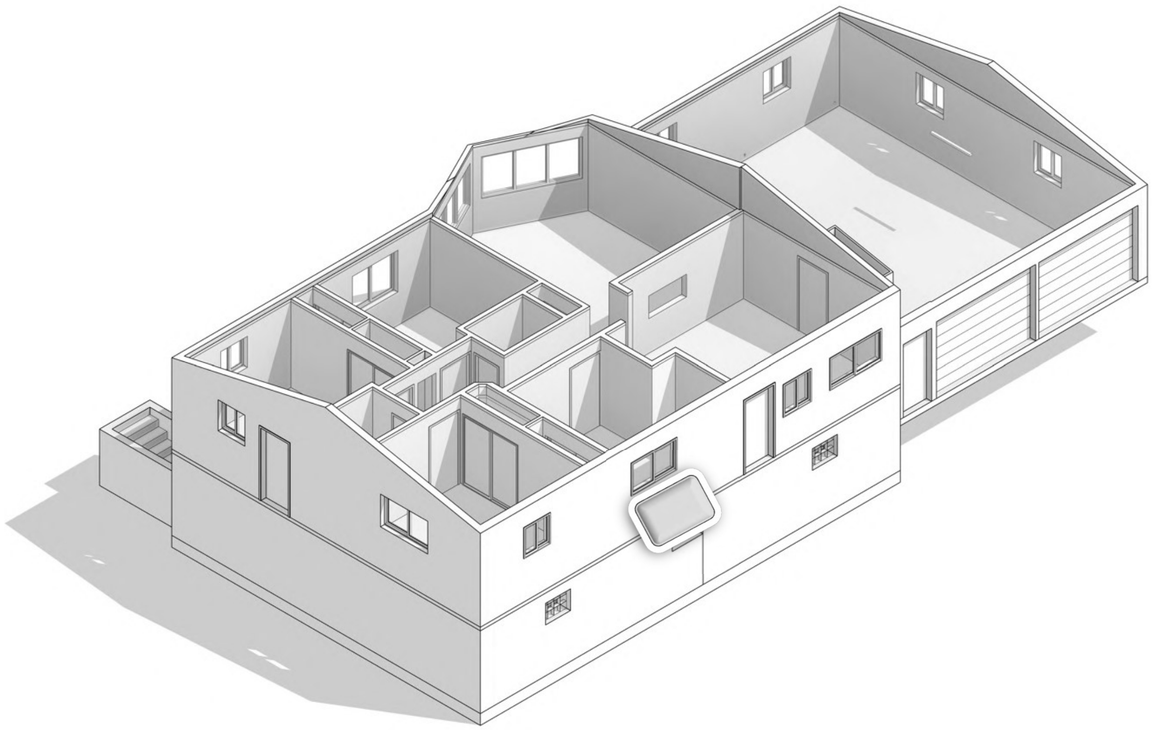

Figure 4: 3D Building Information Modeling (BIM) from Matterport 3D scan (Dimensions are in the BIM file; note: the yellow box indicates the location of the smoker's shed).

3.2 *EYEWITNESSES, FIRE DEPARTMENT, AND DISPATCH DATA*

Matthew Wadsworth, the father, had left for work the evening of January 31, 2022, ~6:10-6:25 pm, and was not present at the house during the fire.[2] Stephanie Wadsworth, the mother, was home at the time of the fire. The children in the home at the time of the fire included Kamille Wadsworth (12 yrs), Gunner Wadsworth (8 yrs), Layne Wadsworth (6 yrs), and Weston Wadsworth (4 yrs). The children went to sleep between 8:00-8:30 pm the night before the fire.[3] Kamille slept in bedroom #1, Weston slept in bedroom #2, and Gunner and Layne slept on bunk beds in bedroom #4 (Gunner on the top bunk, Layne was on the bottom). Stephanie indicated she had smoked a cigarette or possibly several cigarettes in the storage "smoker's" shed before going to sleep on the couch in the living room around 2:00 am on February 1, 2022.[4] Gunner had woken up about 30 minutes before the fire (~3:30 am) to use the bathroom, he did not notice anything out

[2] Matthew Wadsworth Deposition, p. 71

[3] Kamille Wadsworth Deposition, p. 29; Gunner Wadsworth deposition, p. 12

[4] Stephanie Wadsworth Deposition, p. 87-88

of the ordinary at that time.[5] Gunner was awakened with "fire behind me; it had melted through the window and had moved up the wall" and the first thing he remembered was "the fire behind my back" with the "fire by the window," and that there "was no window when he woke up because the fire had melted both pieces of the window."[6] Gunner repeated this later in his deposition when he testified his back would have been towards the window, and that the heat was on his back, and that he first saw fire at the bedroom window area.[7] Kamille was awakened by the smoke alarms and yelling by Gunner and Layne. When Kamille was walking through the hallway to the living room she looked into bedroom #4 and saw the fire "by the window by their bunk bed,"[8] and that the only thing she saw on fire at that time was the "inside of the wall and their bed."[9] Kamille and Gunner woke up Stephanie. Kamille stated she saw flames outside before Stephanie opened the rear door and Stephanie had to close the door quickly because there was too much smoke and flames at the door.

Mr. Ryan Pasborg, a volunteer firefighter, was alerted to the fire when he left his house for work ~3:55AM on February 1, 2022.[10] He noticed "medium sized flames…could see the glow 'from the flames' off the clouds,"[11] when he pulled onto HWY374 (~1+miles away from 1620 HWY 374). When Mr. Pasborg arrived at the structure, he noticed flames extending out of bedroom #4 window and flames along the ground under the window "calf level" in height.[12] Mr. Pasborg does not remember seeing a shed in front of bedroom #4 window when he arrived.[13] Mr. Pasborg testified Kamille Wadsworth and Gunner Wadsworth were on the exterior structure when he arrived. They told him their mom (Stephanie) and younger brother (Weston) were still inside the structure. Mr. Pasborg entered the structure through the pedestrian door to the garage and then into the house through the kitchen door. Mr. Pasborg noted that the smoke and heat were intense in the kitchen with the smoke layer approximately 4 feet above the floor, which forced him to crawl to search.

[5] Video of Gunner Wadsworth interview by Sheriff's department, 7:47
[6] Video of Gunner Wadsworth interview by Sheriff's department, 3:40-6:50
[7] Gunner Wadsworth Deposition, p. 17-20
[8] Video of Kamille Wadsworth interview by Sheriff's department, 36:00-39:00
[9] Kamille Wadsworth deposition, p. 33-36
[10] Ryan Pasborg Deposition, p. 24-26
[11] Ibid, p. 26
[12] Ibid, p. 33
[13] Ibid, p. 86

He found Weston crawling ~5 feet from the kitchen/garage door and took Weston to Kamille outside the house. Mr. Pasborg then entered the structure again and found Stephanie Wadsworth gurgling and unconscious ~7.5-8 feet from the kitchen door and drug her outside (Figure 5).[14]

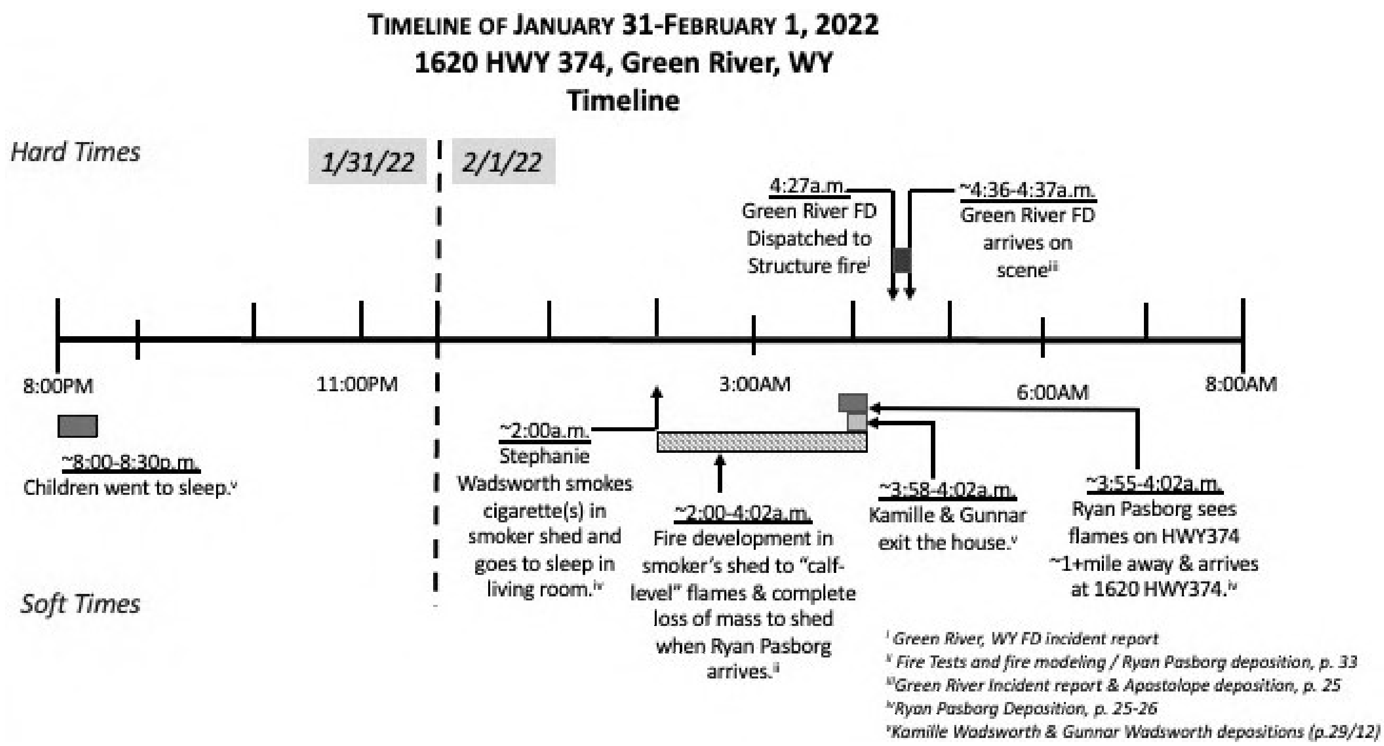

Figure 5: Timeline of events

3.3 Materials and Fuels

The contents and lining materials used within a structure are important variables in how the fire develops, grows, and spreads.[15] Specifically, the peak heat release rates (HRR) and the time it takes for fuels to reach the peak heat release rates are important fire variables for life safety. The contents and lining materials for bedroom #4 and the smoker's shed are described below.

3.3.1 Bedroom #4

Bedroom #4 was lined with wood paneling. Wood paneling burns at a rate between 225-530 kW/m^2.[16,17] A surface area of approximately 368 ft^2 (34.2 m^2) would give an approximate potential

[14] Ryan Pasborg deposition, p. 39-45
[15] NFPA 921, 2017, chapter 22
[16] Xu, Q., Zachar, M., Majingova, A., Jin, C., & Jiang, Y. (2003) "Evaluation of plywood fire behavior by ISO tests", European Journal of Environmental and Safety Sciences, 1(1), 1-7
[17] Bryner, N., Madrzkywoski, D., & Grosshandler, W. (2007) "Reconstructing the Station Nightclub Fire: Materials Testing and Small-Scale Experiments". International Interflam Conference, 11th Proceedings, Volume 2, London

heat release rate of 7695-18,126 kW if all the wood paneling were ignited and burned. A bunk bed was also located along the east wall of the bedroom near the window, which would contribute approximately 4,800-6,250kW and would reach this peak in approximately 200-300s (Figure 6).[18, 19] A hoverboard was located along the north wall of the bedroom near the closet door. The hoverboard would have approximately a peak heat release of ~500kW and reach this peak in less than 20-30 seconds based on flame heights during actual fires captured by videos of similar hoverboards burning. Combining the wood paneling, hoverboard, and bunk bed could produce peak heat release rates of 12,995-24,876kW.

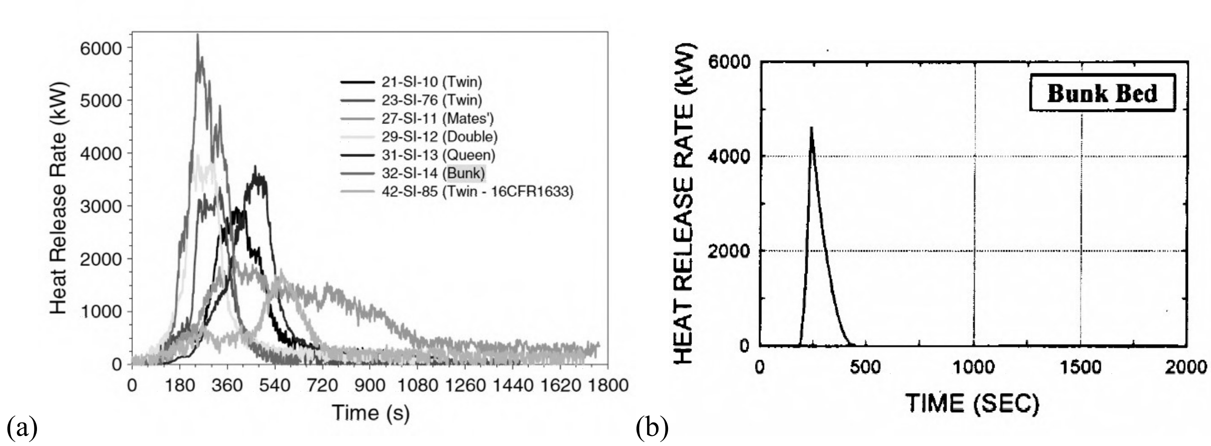

Figure 6: Heat release rates of bunk beds (a)Bwyala study, (b) Kim study

3.3.2 Storage "Smoker's" Shed

Eagle manufactured the storage shed, a 4-drum poly outdoor storage drum, Model 1649.[20] Eagle's advertising and marketing material indicates the storage shed is high-density polyethylene. A sample of the shed was sent for Fourier Transform Infrared (FTIR) Spectroscopy analysis, which confirmed the material that the shed was composed of was polyethylene. No fire test data could be found of this type of shed burning. Therefore, an exemplar of the shed was purchased, and a fire test was conducted (Figures 7-10). The test consisted of an exemplar shed filled with similar materials identified in the shed, including a wood chair in the northeast corner, a heater, a small

[18] Bwyala, A., Gibbs, E., Lougheed, G., & Kashef, A. (2015). "Heat Release Rates of Modern Residential Furnishings during Combustion in a Room Calorimeter," Fire and Materials, doi: 10.1002/fam.2259, p.706
[19] Kim, H., Lilly, D. (2000). 38th Aerospace Sciences Meeting & Exhibits, Reno, NV.
[20] Matthew Wadsworth deposition, p. 101

end table in the southeast corner, a metal chair in the southwest corner, and a comforter/blanket (Figure 8).[21] Based on the fire test of the shed, the peak heat release rate was approximately 3,000-5,000 kW, which reached this peak in approximately 400-450 seconds, assuming a flaming ignition of the comforter (Figure 7). This fire could have smoldered before transitioning into flaming combustion due to the type of fuels and potential ignition sources. Research has been conducted on the length of time it takes for a cigarette to transition from smoldering to flaming combustion, which states "this transition from smoldering to flaming does not occur in all cases; when it does, times from placement of the cigarette to flaming of ***22 minutes to several hours*** have been reported".[22] Flame heights exceeded 20 feet (6.1m).

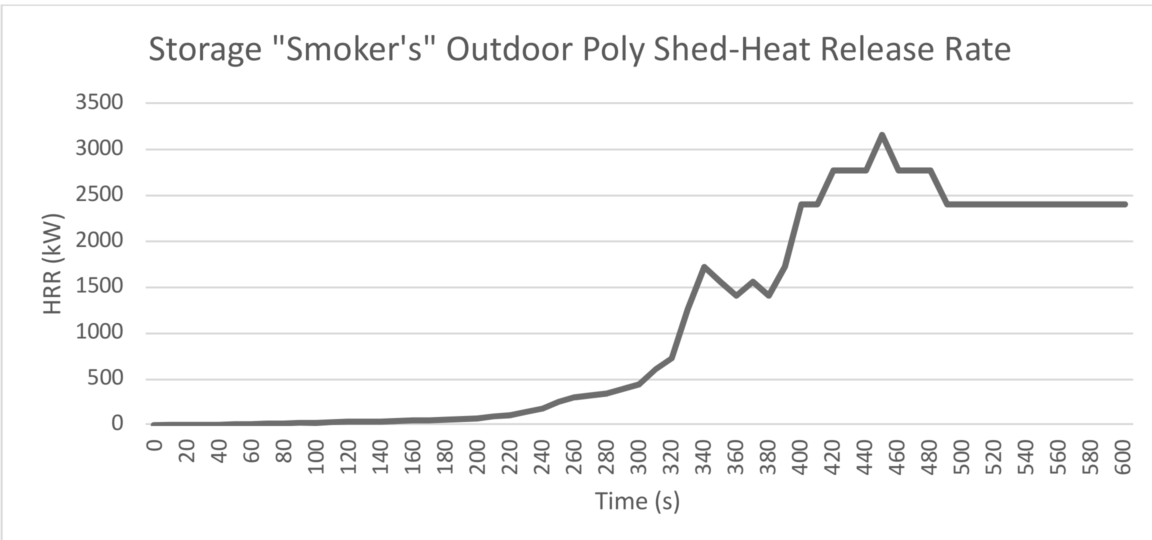

Figure 7: Heat Release Rate for Outdoor Storage Shed (based on fire test data)

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[21] Ibid, and Stephanie Wadsworth deposition

[22] Braun, E., et al., "Cigarette Ignition of Upholstered Chairs," Journal of Consumer Product Flammability, Vol. 9, 1982, pp. 167–183. Babrauskas, V., and Krasny, J. F., "Upholstered Furniture Transition from Smoldering to Flaming," Journal of Forensic Sciences, Vol. 42, 1997, pp. 1029–1031.

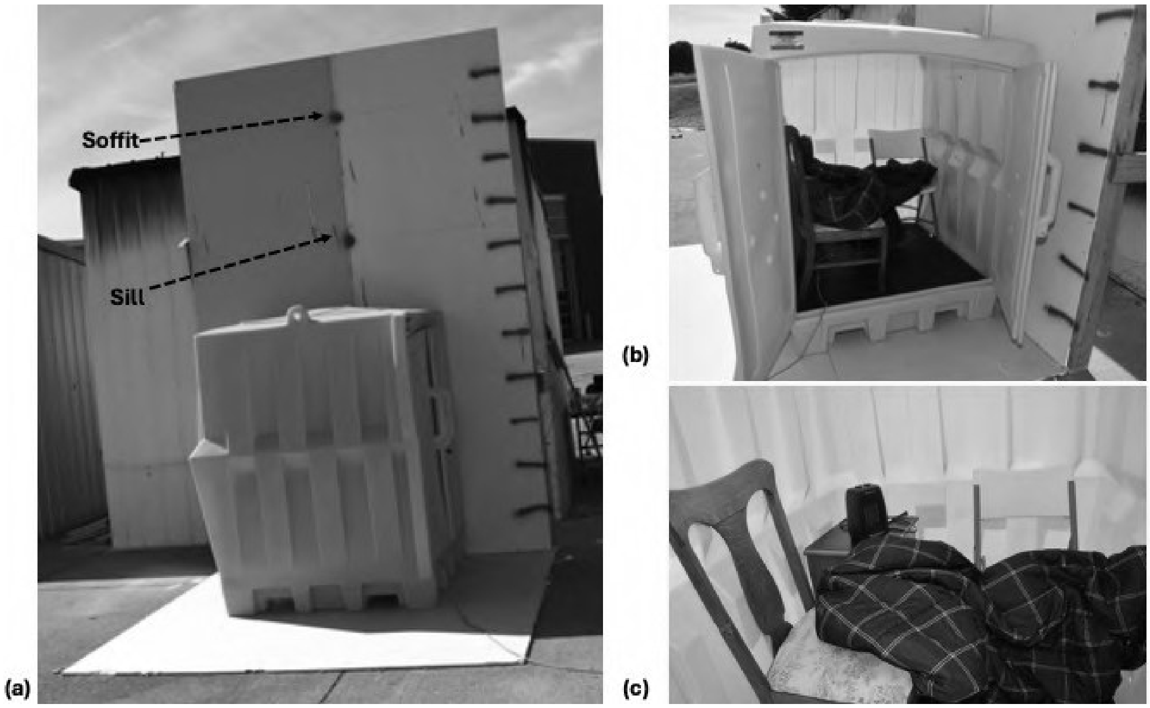

Figure 8: Test Setup (note: two 12-ft sheets of drywall are positioned behind the storage shed) (a) exterior, (b) interior with chairs & comforter/blanket, (c) interior corner with end table & heater

Figure 9: Fire Test Results (note: the fire was extinguished ~9.5 minutes [570s] due to fire spreading to surrounding structures; pool fire continued to burn with flame heights ~4-5ft)

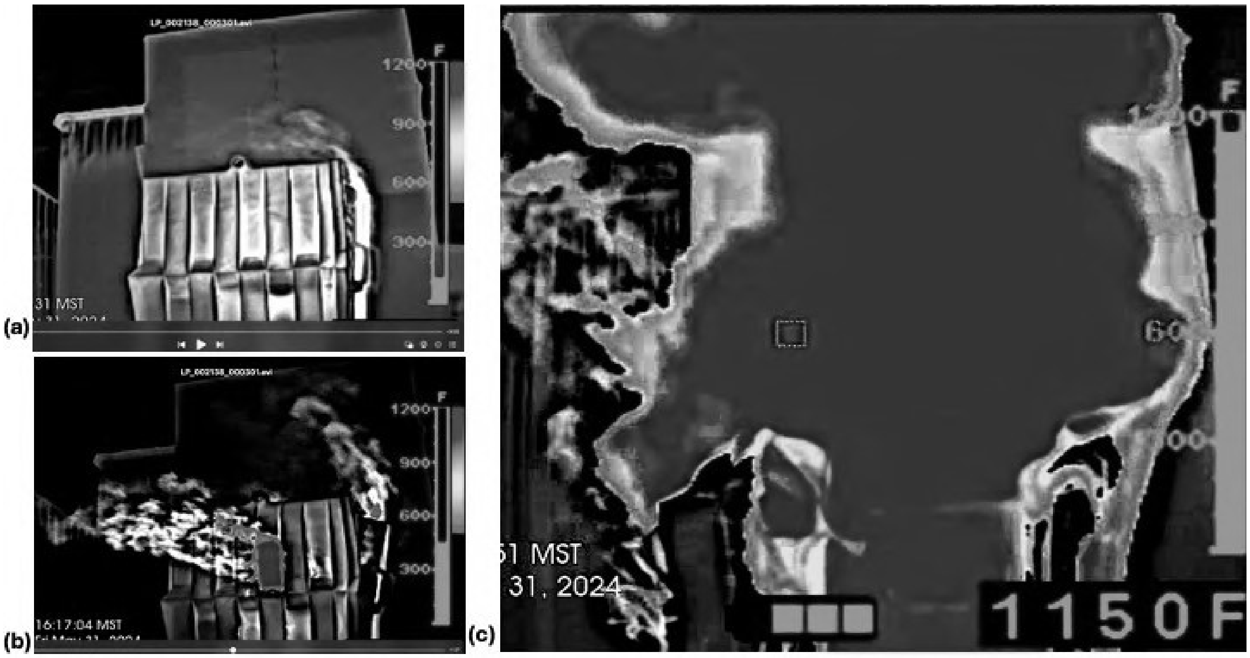

Figure 10: Thermal Imaging Camera Results (a) ~180s, (b) ~300s, (c) ~400s

4.0 DATA ANALYSIS

4.1 Computational Fluid Dynamic (CFD) Simulations

Computational fluid dynamic (CFD) simulations were performed to (1) evaluate the governing physics of the fire spread throughout the house, (2) consider alternative hypotheses regarding different origins, and (3) analyze post-fire damage in comparison to the predicted heat transfer from the various computer simulations to the physical evidence from the fire at 1620 HWY374, Green River, WY.

In summary, the simulations showed that a single origin at the exterior storage “smoker’s” shed better replicated the actual fire damage in the structure and better correlated to the witness statements and timeline. The Plaintiff’s hoverboard origin theory does not accurately reflect the witness statements or the physical evidence after the fire. The following sections outline the modeling approach and assumptions and provide additional results and discussion.

To test the hypotheses, a CFD model, Fire Dynamics Simulator (FDS, v.6.9), and its accompanying visualization software, SMOKEVIEW, were utilized.

1) *Purpose of Computer Fire Models*

Computer fire models have many applications, including the design and analysis of fire protection systems (i.e., sprinkler systems, detection systems), evaluation of the effects of fire on people and property, postfire reconstruction, and fire risk assessment.[23] Computer fire modeling is widely used in designing and evaluating the fire safety of buildings and facilities. They are being implemented into several United States national building codes and fire safety standards, including NFPA 72 *National Fire Alarm Code*, NFPA 101 *Life Safety Code*, and NFPA 5000 *Building Construction and Safety Code*.[24]

2) *Use, Validation, Verification, and Limitations of Computer Fire Models*

As mentioned above, computer fire models were created to support design applications. Therefore, design applications have undergone considerable validation work by the model developers.[25]

According to the National Institute of Standards and Technology [NIST], the developers of the computer fire model *Fire Dynamics Simulator* [FDS], validation is defined as the "process to determine the appropriateness of the governing equations as a mathematical model of the physical phenomena of interest."[26] The developers of FDS caution, however, that the model's validation comes down to three major issues, "(1) comparing model predictions with experimental measurements, (2) quantifying the differences in light of uncertainties in both the measurements and the model inputs, and (3) deciding if the model is appropriate for the given application".[27]

NFPA 921, the *Guide for Fire and Explosion Investigations*, is the authoritative standard of care for the fire investigation profession and provides further guidance on how computer fire models should be applied to fire investigations: "Mathematical modeling techniques provide the investigator with tools for testing hypotheses regarding origin and cause of the fire/explosion and the cause of the resulting damage to property or injury to people."[28]

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[23] Wood, et. al (2008). *Applying Fire Models to Fire Protection Engineering Problems and Fire Investigations.* Fire Protection Handbook 20th Edition. NFPA: Quincy, MA, p. 3-112.

[24] NFPA (2007). *National Fire Codes*. National Fire Protection Association: Quincy, MA.

[25] NIST Special Publication 1018-3 Sixth Edition (2022), Fire Dynamics Simulator Technical Reference Guide, Volume 3: Validation, p.6

[26] Ibid, p.vii

[27] Ibid, p.vii

[28] NFPA (2024). *NFPA 921-Guide for Fire and Explosion Investigations*. Section 21.4.1.

The requirements set forth by NIST and NFPA 921 in evaluating if a computer fire model has been correctly applied to fire investigations include the following: (1) the model must be validated and verified for how it is being used, (2) the physics of the fire model must accurately predict the actual physical phenomena and should match the physical evidence remaining after the fire, and (3) the model should be used to test hypotheses and therefore is bound by the scientific method.[29] Each requirement will be analyzed against the computer fire modeling performed.

4.1.1 Approach

The approach involves:

1. Building a geometry model of the structure at 1620 HWY 374, Green River, WY, from photographs, diagrams, 3D Scan/BIM file from Matterport, and dimensions provided by original investigators.
2. Modeling fire growth and sizes consistent with the evidence and the scientific literature on compartment fires.
3. Monitor the heat transfer and temperatures along the walls, ceiling, windows, and content lining materials to determine the location, duration, and intensity of heating and compare it to the physical damage during the actual fire.

More than 45 simulations were conducted. The computer fire modeling simulations are titled numerically with the name of the case, followed by the simulation number (e.g., *Wadsworth_#*). These simulations all had the same geometry for the house. The numerical mesh was varied to determine the sensitivity of this variable on the output. Many other variables were evaluated throughout these 45+ simulations, including ventilation opening criteria, peak HRR, time to peak HRR, thermo-chemical properties, material properties, fuel characteristics, and combustion reaction characteristics. To best evaluate the influence of each variable, the simulations were grouped according to major adjustments in the simulations, and a sensitivity analysis was performed on the impact of the governing variables. A letter was added to the end of the simulation number for these simulations (e.g., *Wadsworth_#a,b,c…*).

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[29] NIST Special Publication 1018-3 Sixth Edition (2022), Fire Dynamics Simulator Technical Reference Guide, Volume 3: Validation, p.5

4.1.2 Geometry and Environmental Conditions

A computer model of the structure was built using floor plans provided by the original investigators, a Matterport 3D scan/BIM file, and diagrams provided by witnesses (Figure 8). The local weather at the time of the fire was a temperature of ~11°F (11°C) and a wind from the W, WNW at ~12-13mph (5.3-5.8 m/s).[30] The environmental conditions were varied throughout the simulations to evaluate the influence of this on the conclusions.

Figure 11: Geometry of CFD simulations(top) West/front of structure, (middle) East/rear of structure, (bottom) East/rear of structure with Storage "Smoker's" Shed and numerical mesh

[30] Wunderground historical weather for Rock Springs, WY (~15 miles East of Green River, WY)

The computational cell size needs to be specified since CFD models use a numerical grid to solve a form of the conservation of mass, momentum, and energy equations. A non-dimensional expression, $D^*/\delta x$ can be used to estimate how well a flow field is measured.[31] The D*/dx ratios for the fuel package models in these simulations fell within the moderate mesh range when using a ~15-20cm grid spacing. This allowed for accurate simulations.

4.1.3 Fire Growth and Spread Scenarios

Two hypotheses related to origin were considered: (1) a single origin located within bedroom #4 at the hoverboard, and (2) a single origin hypothesis in the exterior storage "smoker's" shed. Each origin hypothesis was simulated numerous times with varying heat release rates (time to and peak), combustion characteristics, properties of lining materials, and ventilation opening criteria.

The hoverboard is the fuel package within bedroom #4, which Messrs. Schultz and King identified as an area of origin and will be the predominant fuel for bedroom #4 origin. Additional fuels within the bedroom that added to the fire once ignited included wood paneling and the bunk beds. Test data reflecting actual heat release rate curves and peak heat release rates of fuel packages located at the area of origin (i.e., hoverboard, wood paneling) for the various hypotheses were used as described in sections 3.3.1 and 3.3.2 of this report. The heat release rate values and combustion characteristics of the larger fuels are essential to the governing physics and conclusions drawn from these simulations; these values were varied throughout the simulations to identify any influence they had upon the conclusions.

The thermo-chemical material properties of solid objects were included in the simulations to accurately reflect the physics of heat transfer, including density, specific heat, thermal conductivity, heat of combustion, and ignition temperature. The thermo-chemical properties for the fuels and lining materials were determined through research of reference literature of similar

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[31] McGrattan, K., Glenn, F., "Fire Dynamics Simulator (Version 6) – User's Guide," National Institute of Standards and Technology, 2015.

materials.[32,33,34] The input values for the combustion characteristics of the wood paneling were similar to those identified in sections 3.3.1-3.3.6 of this report based on actual test data.[35]

Ventilation or vents in FDS are openings from the compartment to outside ambient conditions or to another compartment. The windows, doors, and attic vents are major sources of ventilation considered in these simulations. A significant factor in fire development within most fire scenarios, precisely this scenario, was the failure of windows and their impact on fire conditions. The first set of simulations conducted (Wadsworth_1-Wadsworth_8) did not remove any of the ventilation to determine the baseline influence of the compartment alone on the fire development. Glass fracture and window failure were added later to remove these openings based on temperature exposure automatically. The bedroom #4 window was independently controlled throughout the simulations by devices set within the simulation to record temperatures accurately. Research has concluded that windows of various glass thicknesses (3-6mm) will begin cracking at gas temperatures between 150°-175°C and will fail at gas temperatures between 300°-450°C, with the thicker glass failing at higher gas temperatures.[36] A device located at the center of each window served as an obstruction-controlled window failure. Numerous simulations were conducted with varying temperatures for failure of the windows, but the range of temperatures was established for failure when the device recorded a gas temperature between 275-450°C. The attic vent in the hallway outside of bedroom #4 was also added as passive and active.

4.1.4 Predicted Damage from CFD Simulations

The visual identification of surface damage progression to wood paneling when it begins to pyrolyze and decompose. Wood paneling begins to degrade above 200°C, which produces combustible gases thermally, and as the temperature reaches nearly 300°C, the remaining material experiences the formation of char.[37] The Boundary Temperature application, evaluating temperature along the lining surfaces within the FDS model, was used to compare the conditions

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[32] Hurley, M. (2016) *SFPE Handbook of Fire Protection Engineering*, New York, Springer.
[33] Babrauskas, V. (2003) *Ignition Handbook*. Issaquah: Fire Science Publishers.
[34] UMD Fire Protection Engineering Department, *University of Maryland Burning Item Database.*
[35] Matala, A., Hostikka, S., & Mangs, J. "Estimation of Pyrolysis Model Parameters for Solid Materials Using Thermogravimetric Data," VTT, Fire Safety Science-Proceedings of the 9th International Symposium, p. 1213-1224.
[36] Babrauskas, V. (1998) "Glass Brekage in Fires", Fire Science and Technology Inc.
[37] Hurley, M. (2016) *SFPE Handbook of Fire Protection Engineering*, New York, Springer.

to the wood paneling in the structure to those predicted by the simulations. Using FDS to evaluate char patterns and the influence of ventilation throughout a compartment is a reliable application of this CFD model.[38]

Virtual slices through the simulations are included to evaluate the growth and spread of the fire and airflow from ventilation openings throughout the structure. Slice files illustrating temperature, gas species, visibility, and smoke flow have been added throughout the simulations.

4.1.5 Devices and Slice Files

FDS allows the user to program a few different options for measuring tools. The first is devices. For the simulations for this report, a smoke detector was placed like that in bedroom #4 on the day of the fire (Figure 12). The timing for each activation of these devices was recorded. The smoke detectors were programmed with varying subroutines using the Heskestad and Cleary models (Figure 13). To evaluate the sensitivity of the simulation findings, the parameters for these smoke detectors were varied to assess the influence of the conclusions.

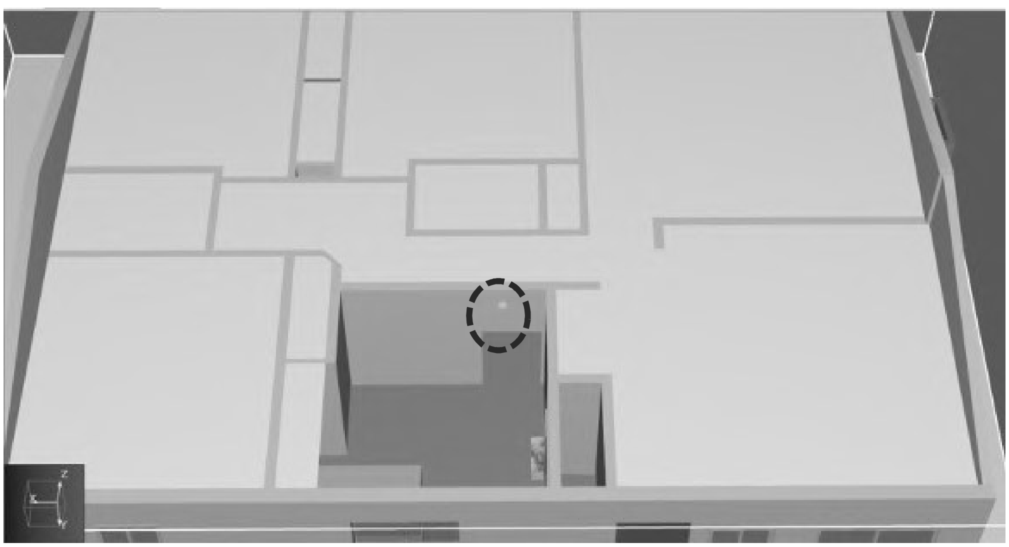

Figure 12: Smokeview Aerial View-Showing Location of Bedroom #4 and Fire Protection Devices (note: dashed circle indicates location of the smoke alarm in Bedroom #4)

[38] Li, K., Wang, J., Ji, J. (2014). "An Experimental Investigation on Char Pattern and Depth at Postflashover Compartments Using Medium-density fibreboard". Fire and Materials, Wiley, DOI:10.1002/fam.2291

Detector	α_e	β_e	α_c, L	β_c
Cleary Ionization I1	2.5	-0.7	0.8	-0.9
Cleary Ionization I2	1.8	-1.1	1.0	-0.8
Cleary Photoelectric P1	1.8	-1.0	1.0	-0.8
Cleary Photoelectric P2	1.8	-0.8	0.8	-0.8
Heskestad Ionization	—	—	1.8	—

Figure 13: Smoke Detector Parameters that were Varied

The next type of measuring method used in these simulations is slice files. FDS allows the programming of slices to be placed at specified locations within the model at a specified x, y, or z coordinate. The slices are only allowed one coordinate on the x, y, or z axis and cut through the entire domain (Figure 14). These slices can then be viewed in smokeview with a color scale to measure levels of severity. This report's slice files were programmed to measure temperature and gas yields at several elevations from the ground level on the z-axis. 3-dimensional slice files were also added for gas species, soot concentrations, FED concentrations, and temperature (Figure 14).

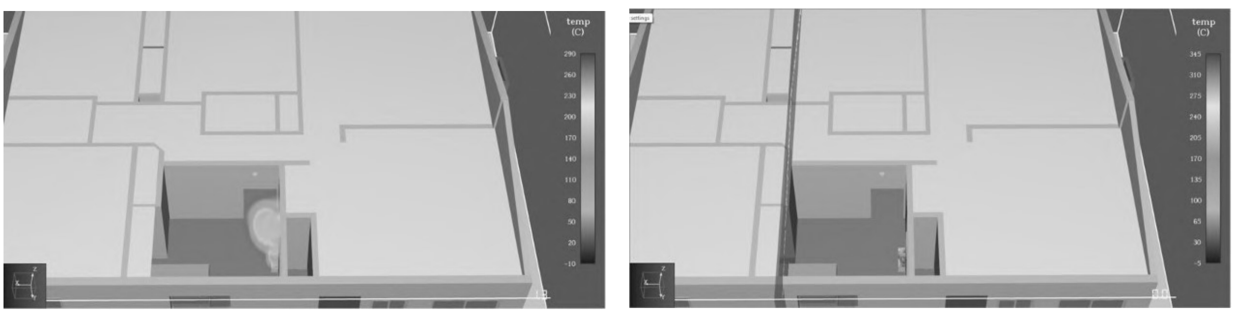

Figure 14: Example of Slice Files used in the simulations (left) 3D Slice for Temperature, (right) 2D slice for temperature

4.1.6 Tenability Criteria

The FDS model can provide detailed numerical output quantities of conditions within modeled spaces. Specific tenability criteria have been developed to assess the presence of combustion products and the environment.

The tenability criteria are threshold values that, once exceeded, can immediately impact the life and health of evacuating occupants. The criteria for tenability are developed from the SFPE

Handbook and other sources.[39,40] The tenability criteria will be evaluated at heights above all walking surfaces and measured in FDS. The tenability criteria used in this report are in table 1.

Table 1: Tenability Criteria

Tenability Parameter	Performance Criteria
Temperature	140°F (60°C)
Carbon Monoxide	150 ppm for 30 minutes, 420 ppm for 10 minutes
Fractional Effective Dose (FED)	1.0 combination of gases

Temperature: Temperature tenability measures the temperature that occupants are exposed to during evacuation. The value for occupants' exposure to elevated temperatures is an instantaneous exposure to a temperature of 60°C or more, six (6) feet above the egress paths. Considering there are juveniles in this home during the fire, three (3) feet above the egress path will also be reported. The 4th Edition of the SFPE Handbook (Section 2, Chapter 6) [41] indicates that 60°C is the highest temperature at which 100% humidity air can be inhaled for a short period. As fires can produce large amounts of water vapor due to combustion and firefighting activities, this criterion for 100% humidity air was conservatively identified as the temperature tenability limit.

Fractional Effective Dose (FED): The fractional effective dose is a commonly used measure of incapacitation of humans due to exposure to combustion gases. The FED value is calculated as

$$\mathrm{FED_{tot}} = (\mathrm{FED_{CO}} + \mathrm{FED_{CN}} + \mathrm{FED_{NO_x}} + \mathrm{FLD_{irr}}) \times \mathrm{HV_{CO_2}} + \mathrm{FED_{O_2}}$$

As an example, the fraction of an incapacitating dose of CO is calculated as:

$$\mathrm{FED_{CO}} = \int_0^t 2.764 \times 10^{-5} \left(C_{\mathrm{CO}}(t)\right)^{1.036} \mathrm{d}t$$

The time to loss of tenability from the effects of smoke, toxic gases, or heat is then calculated as the time at which each endpoint reaches an FEC or FED of 1.[42]

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[39] Fire Safety Engineering, CIBSE Guide E, 2010 Edition.
[40] Assessment of Hazards to Occupants from Smoke, Toxic Gases, and Heat, David A. Purser and Jamie L. McAllister, SPFE Handbook of Fire Protection Engineering, 4th Edition.
[41] Assessment of Hazards to Occupants from Smoke, Toxic Gases, and Heat, David A. Purser and Jamie L. McAllister, SPFE Handbook of Fire Protection Engineering, 4th Edition.
[42] SFPE (2016) Handbook of Fire Protection Engineering. Society of Fire Protection Engineers.

Carbon monoxide: Carbon monoxide (CO) measures the toxicity of smoke that occupants are exposed to during evacuation. Carbon monoxide (CO) causes the formation of carboxyhemoglobin in the bloodstream when inhaled, with the severity being determined by exposure time and concentration of carbon monoxide. The EPA has established a federal recommendation for CO to avoid health effects. The EPA recommends that no person exceed an exposure of 420 ppm in 10 minutes, 150 ppm in 30 minutes, and 83 ppm in 60 minutes[43].

4.1.7 Sensitivity Analysis

The accepted and peer-reviewed methodology for using computer fire models is to provide a range of variables to evaluate both the sensitivity of the model and ensure that the variables that are not explicitly known are accounted for within the series of models. [44,45] Using modeling for fire investigation and reconstruction must follow a similar methodology. The user must input a range of variables based on the scenario, the collected data, and the probable hypotheses. This variation of the input variables will affect the output or outcomes of the model and provide the user with a range to utilize in their analysis.

A sensitivity analysis was performed on all pertinent variables that would have influenced the findings for smoke detector activation, location and magnitude of damage, and tenability limits. The sensitivity analysis is encompassed within the summary of the results, as the number of simulations performed for this scenario varied over 45 times.

5.0 HYPOTHESES TESTS AND RESULTS

Michael Schulz, the Plaintiff's fire investigator, concluded the "origin of the hostile fire incident was located on the west wall of the bedroom on the north side of the bedroom hallway immediately adjacent to or behind the kitchen."[46] This location's description is nonsensical, as the directions used in his description of origin do not match those used in Mr. Schulz's report. However, Mr. Schulz identified the cause as "to be the ignition of the combustibles…in the artifact Jetson

[43] Environmental Protection Agency AEGL-2. http://www.epa.gov/oppt/aegl/pubs/carbon_monoxide_final_volume8_2010.pdf

[44] NFPA (2008). *Fire Protection Handbook*. National Fire Protection Association. Quincy, MA.

[45] SFPE (2009). *Guidelines for Substantiating a Fire Model for a Given Application.* Society of Fire Protection Engineers

[46] Schulz report, p. 76

hoverboard located within the area of origin…”.[47] It is assumed that Mr. Schulz is indicating the location of the hoverboard in Bedroom #4 as the fire’s origin. Mr. Derek King, the Plaintiff’s engineer, also confirms that the Plaintiff’s experts area of origin is “the Jetson hoverboard.”[48] The Plaintiff’s origin theory put forward by Mr. Schulz rests on “the observations of witnesses,” the “application of arc mapping”, the “evaluation of fire dynamics…, fire development and fire plume progression and development,” and the “analysis of the fire patterns… analysis of the distribution of thermal damage present”.[49] The alternative origin hypothesis by Mr. Joseph Filas, fire investigator for Rimkus Engineering, is that the fire originated within the outdoor storage “smoker’s” shed and spread through the Bedroom #4 window.

The fundamentals of fire dynamics can be used to test hypotheses regarding fire origin.[50] Fire modeling was used here to assist with evaluating the fundamentals of fire dynamics. The governing physics will be compared to the progression of fire throughout the structure, ignition of fuels remote from the origin, failure of windows, tenability conditions, and activation of the smoke alarms. These governing physics will then be compared to witness statements and the timeline from these statements to corroborate or refute hypotheses. Empirical correlations for fire dynamics and the computational fluid dynamics (CFD) model, fire dynamics simulator (FDS), were implemented to evaluate the competing hypotheses. The empirical correlations will be addressed first in Section 5.1, and then the CFD simulations will be addressed second in Section 5.2.

5.1 Empirical Correlations

Empirical correlations for fire dynamics were implemented to evaluate the competing hypotheses. These correlations are based on experimental data and testing over the past 80 years of fire testing and research. These correlations are predominantly based on experimental work explicitly addressing specific phenomena. The two that assist in testing hypotheses in this scenario are the radiant heat transfer from a flame and flashover correlations. The flashover correlations will be combined with the damage to the room and the witness statements. The determination of whether bedroom #4 reached full-room involvement through flashover is essential for evaluating tenability

[47] Schulz report, p. 79
[48] King report, p. 3
[49] Schulz report, p. 76-78
[50] NFPA 921 (2024) 18.6.2.2

within this space and what influence the fire development within the room would have on the location and magnitude of damage in relation to flow paths of air throughout the compartments. The radiant heat transfer calculations are based on the first principles of heat transfer and are used to evaluate the heat transfer to the bunk bed and the rear bedroom wall where the window was behind the bunk bed.

5.1.1 Flashover and Full-room Involvement Analysis

Flashover is defined as a transition phase in the development of a compartment fire in which surfaces exposed to thermal radiation reach ignition temperature more or less simultaneously and fire spreads rapidly throughout the space, resulting in full room involvement or total involvement of the compartment or enclosed space.[51] Full-room involvement can be reached without transitioning through flashover.

As a fire transitions to full-room involvement[52], it becomes ventilation-controlled.[53] Ventilation-controlled fires increase the likelihood of misinterpreting visible fire patterns because unburned hydrocarbons (fuel vapors) are produced during this phase of the compartment fire but lack sufficient oxygen for combustion. The burning during ventilation-controlled conditions is often detached from a fuel item (i.e., wood chair), and the unburned fuel will burn near ventilation openings and along airflow paths (i.e., doors, windows) when sufficient oxygen for combustion exists.[54, 55, 56]

The damage that a fire investigator identifies after a fire that has reached full-room involvement may be caused by the airflow path and mixing during this stage of the fire rather than damage associated with the true origin. Investigators have been shown to misinterpret the area of origin because of this damage. A study published in 2008[56] divided the room into four quadrants and

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[51] NFPA 921, 2024), Section 3.3.96
[52] NFPA 921, 2024, 3.3.102* *Full Room Involvement.* Condition in a compartment fire in which the entire volume is involved in combustion of varying intensities.
[53] NFPA 921, 2024, 3.3.211 Ventilation-Controlled Fire. A fire in which the heat release rate or growth is controlled by the amount of air available to the fire.
[54] Custer and Wright, 1984
[55] Shanley et al., 1997
[56] Carman, 2008

surveyed the attendees to derive an error rate study of investigators. It reported a 5.7% success rate of determining the correct quadrant of origin in a one-room compartment fire with a single door opening, which is very similar in layout to the fire in this home. The study indicated that those investigators who were wrong identified an incorrect origin because they were misled during their analysis by extensive, post-flashover generated burn patterns. Another study evaluated the investigators' ability to determine the area of origin in a post-flashover compartment that persisted for ~2 minutes after flashover and found that 73.8% of the ~590 participants could correctly determine the area of origin. However, this study also showed that participants who incorrectly identified the area of origin needed clarification on the damage near the ventilation openings.[57] While it was known that research existed pre-2008 regarding the influence of ventilation locations on post-flashover generated fire patterns, it needed to be more mainstream and focused on more training and fire investigation literature. Since 2008, evaluating ventilation openings in relationship to damage has become a greater focus for training and education in fire investigation.[58]

One accepted way of determining if flashover or full-room involvement had occurred is by looking at the damage within the compartment after a fire. The Bureau of the Alcohol, Tobacco, and Firearms (ATF) federal fire investigation laboratory identified and established training for identifying specific indicators and characteristics of flashover and full-room involvement that all fire investigators should recognize.[59] NFPA 921 (2024) combined these indicators into section 6.2.1.8.2, which includes the following:

1. Witnesses seeing flames extending out of openings or broken windows,
2. Hot gas layer descending to the floor resulting in no observable, horizontal line of demarcation on the walls,
3. Floor-to-ceiling charring and thermal damage,
4. All ignitable fuels in the compartment exhibit burn damage
5. Widespread burning at floor level

The five criteria outlined above were evaluated to determine whether full-room involvement was attained in this compartment fire. Table 2 summarizes these findings. Analyzing the first two criteria requires witness statements, so the firefighter and eyewitness statements were reviewed.

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[57] Tinsley A, Gorbett G (2013) Fire Investigation Origin Determination Survey. Fire and Arson Investigator Journal of the International Association of Arson Investigators 63: 24-40

[58] NFPA 921, 2024, chapters 5-6

[59] CFItrainer.net, Postflashover Fires

The damage within bedroom #4 was used to examine the remaining three criteria. Every combustible content item within bedroom #4 had ignited during the fire and had a significant mass loss. Most of the contents on the floor surface area are ignited and thermally damaged. All walls in bedroom #4 are damaged from floor to ceiling. Bedroom #4's ceiling structure had a complete loss of mass. The upper layer during this fire descended to the floor, causing damage to every elevation within much of the living room, hallway, and bedroom #4. Bedroom #4 reached full-room involvement.

Table 2: Criteria for determining if flashover or full-room involvement was reached using damage

Criteria for determining if flashover or full-room involvement was reached	Collected and Analyzed Data	Flashover / Full-room Involvement attained?
1. Witnesses seeing flames extending out of openings	Mr. Pasborg witnessed flames extending from bedroom #4 window upon arrival. [60]	YES
2.Hot gas layer descending to the floor resulting in no observable, horizontal line of demarcation on the walls	Mr. Pasborg making an interior search identified heavy smoke conditions and substantial heat to ~4 feet from the floor in the structure.[61]	YES
3.Floor-to-ceiling charring and thermal damage	Thermal damage to bedroom #4 has damage floor to ceiling.	YES
4.All ignitable fuels in the compartment exhibit burn damage	Every combustible content within the compartment is in varying levels of consumption.	YES
5.Widespread burning at floor level	All combustible items near or on the floor are partially consumed.	YES

Another way that fire investigators can evaluate whether full-room involvement was attained is to perform simple calculations comparing the size of the compartment and the fuels present. This section of the report aims to determine whether the room could flashover, given a fire originating in that room. The analysis is based on a review of all documents identified in the materials reviewed, the author's education and experience with fire investigation, fire dynamics, and relevant technical literature.

Determination of Flashover Potential

Quintiere indicates that flashover occurs when instability is caused by the power of a fire suddenly exceeding the heat loss and energy flow rates from a compartment.[62] Therefore, the major thing

[60] Ryan Pasborg deposition, p. 25-33
[61] Ibid, p. 25-33
[62] Quintiere, 2017, p.270

to evaluate when determining a space's flashover potential is whether the potential power of fire exceeds the space and ventilation openings (i.e., doors, windows, and heat transfer through the compartment's boundaries).

Heat Release Rate Required to Reach Flashover

Several available correlations have been developed that can be used to determine the minimum heat release rate ($\dot{Q}$) necessary for a compartment to reach flashover. The 'ventilation factor' is considered with most of these correlations where the area of the ventilation opening is multiplied by the square root of the height of the opening. The correlations that have shown the most conservative estimates when compared with experimental data are the following three correlations:

Method of MQH (McCaffrey, Quintiere, and Harkleroad):

$$\dot{Q}=610\left(h_k A_T A_o \sqrt{H_o}\right)^{1/2} \text{ (equation 1)}$$

Method of Babrauskas

$$\dot{Q}=750 A_o \sqrt{H_o} \text{ (equation 2)}$$

Method of Thomas

$$\dot{Q}=7.8 A_T + 378 A_o \sqrt{H_o} \text{ (equation 3)}$$

Where:
$\dot{Q}$ = heat release rate [kW]
A_T =total area of the compartment surfaces [m^2] (subtracting out openings)
A_o =area of the opening [m^2]
H_o=height of opening [m]
h_k = effective heat transfer coefficient [kW/m-K]

The room's dimensions in the flashover calculations were 12' (3.65m) x 11' (3.35m). There was one window and an interior doorway into the hallway (2.5'x6.67' or 0.76m x2.03m). The heat release rate for onset of flashover ranges between ***674-1696kW***. The heat release rates of the fuels in bedroom #4 were significantly greater than the minimum HRR to transition the bedroom through flashover.[63]

[63] Kim, H., et. al, (2000). *Heat Release Rates of Burning Items in Fires*. American Institute of Aeronautics and Astronautics, VA.

Experimental testing of similar fuels and materials demonstrates that the fuels would have the energy necessary to reach the minimum heat release rate (HRR) sufficient to flashover bedroom #4. The minimum HRR necessary for flashover is 674-1696kW. A single twin mattress produces a peak HRR between 300-3800kW, which means that either one of the mattresses burning in that space would have most likely had sufficient power to transition the entire compartment into full-room involvement.[64,65]

It is clear that bedroom #4 reached full-room involvement, evidenced by the damage, witness statements, and heat release rates of the fuel. Therefore, the location and magnitude of fire damage will be influenced by the location of ventilation and the flow paths throughout the compartment. It is equally important to determine when the room transitioned through flashover concerning the witness statements regarding conditions during their escape. CFD modeling assists in evaluating the location/magnitude of damage and the timing to reach full-room involvement. Therefore, the location and magnitude of expected damage and fire development compared to the time to reach full-room involvement are evaluated in Section 5.2 of this report.

5.1.2 Radiant Heat Transfer

All early eyewitnesses mentioned the window and wall behind the bunk bed in bedroom #4, located ~13 feet away from the hoverboard, had ignited early in the event and that the bunk bed had not.[66] The energy required to ignite the wall behind the bed and cause the window to fail ~13 ft from the hoverboard was assessed (Figure 17).

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[64] Ohlemiller, T. (2005). *A Study of Size Effects in the Fire Performance of Beds.* National Institute of Standards and Technology (NIST).

[65] Bwalya, et. al. 2015, Fire and Materials 39: 685-716, Wiley-DOI: 101.1002/fam.2259

[66] Video of Gunner and Layne Wadsworth interview by Sheriff's department

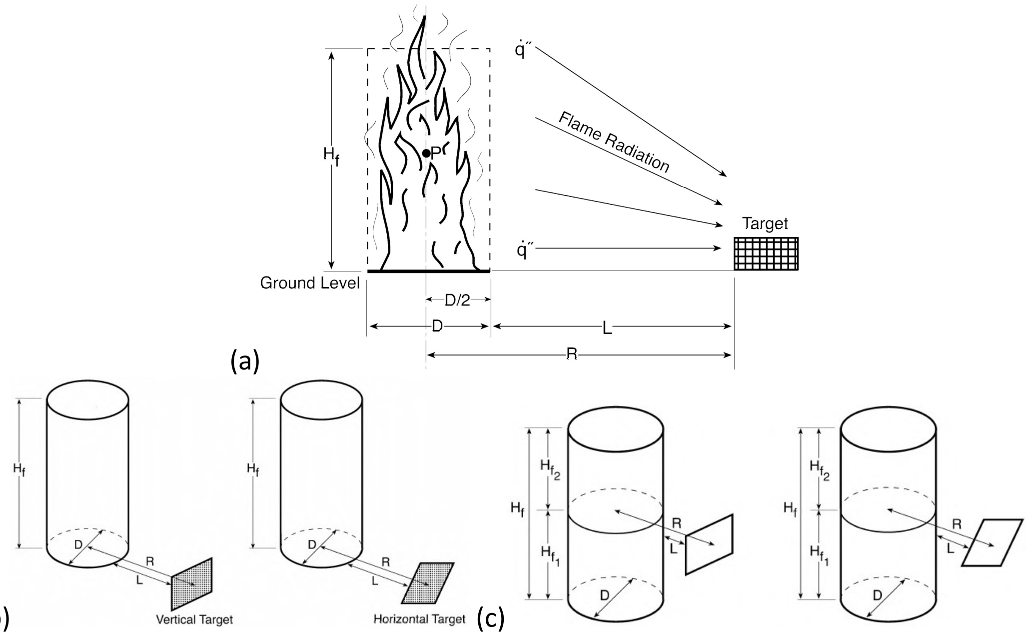

Figure 15: Radiant Heat Flux from a fire to a target fuel (a) Point Source Model, (b) cylindrical flame shape configuration factor geometry for vertical and horizontal targets at ground level with no wind, and (c) cylindrical flame shape configuration factor geometry for vertical and horizontal targets above ground with no wind

$$\dot{q}'' = \frac{\chi_r \dot{Q}}{4\pi R^2} \qquad (5\text{-}1)$$

Where:

$\dot{q}''$ = radiant heat flux (kW/m^2)

$\dot{Q}$ = heat release rate of the fire (kW)

R = radial distance from the center of the flame to the edge of the target (m)

χ_r = fraction of total energy radiated

$$F_{1\rightarrow 2,H} = \left(\frac{\left(B - \frac{1}{S}\right)}{\pi\sqrt{B^2 - 1}} \tan^{-1} \sqrt{\frac{(B+1)(S-1)}{(B-1)(S+1)}} - \frac{\left(A - \frac{1}{S}\right)}{\pi\sqrt{A^2 - 1}} \tan^{-1} \sqrt{\frac{(A+1)(S-1)}{(A-1)(S+1)}} \right) \quad (5\text{-}9)$$

$$F_{1\rightarrow 2,V} = \left(\frac{1}{\pi S} \tan^{-1}\left(\frac{h}{\sqrt{S^2 - 1}}\right) - \frac{h}{\pi S} \tan^{-1} \sqrt{\frac{(S-1)}{(S+1)}} + \frac{Ah}{\pi S\sqrt{A^2 - 1}} \tan^{-1} \sqrt{\frac{(A+1)(S-1)}{(A-1)(S+1)}} \right) \quad (5\text{-}10)$$

Where:

$$A = \frac{h^2 + S^2 + 1}{2S}, \quad B = \frac{1 + S^2}{2S}$$

$$S = \frac{2L}{D}, \quad h = \frac{2H_f}{D}$$

And:

L = the distance between the center of the cylinder (flame) to the target (m)
H_f = the height of the cylinder (flame) (m)
D = the cylinder (flame) diameter (m) [67]

It is important to note that radiant heat transfer is equally distributed 360º around the combustion flame and that the distance and view factor of the target greatly influences the amount of heat flux received (Figures 16-17). Targets closer and with a better view of the radiator will increase the exposure. Therefore, using the estimated heat release rate for the hoverboard as a baseline, the heat flux to items within the room may be calculated. Following equations 5-1, 5-9, and 5-10, the heat flux from a fire at the hoverboard would have been *67-78% higher* at the corner of the bunk bed than at the rear wall and window behind the bunk bed (Figure 17).[68] It is known that wood and bedding materials have similar critical heat fluxes between [69] ~10-20 kW/m^2.[70] These critical heat fluxes for ignition of the materials are substantially lower than those required to cause pain of 1.7 kW/m^2.[71] Therefore, it is physically impossible for heat transfer from the hoverboard origin hypothesis to avoid the mattresses, bedding, and two boys, so the rear wall behind the bunk bed

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[67] Fire Dynamics Tools Manual (2004)- Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission, NUREG 1805

[68] 6.75ft from hoverboard to the corner of the bunk bed, 500 kW fire is a radiant heat flux of 2.1-2.4 kW/m^2; 13ft from hoverboard to back wall, 500 kW fire is a radiant heat flux of 0.46-0.79 kW/m^2

[69] *Critical Heat Flux:* The heat flux required to adjust the surface temperature to the ignition temperature, Tig, is known as the critical heat flux (CHF).

[70] Nuclear Regulatory Commission (2004), NUREG-1805: Fire Dynamics Tools, p. 6-10

[71] SFPE handbook of Fire Protection Engineering, 2016, p. 2722

should be ignited first. The only hypothesis consistent with the witness statements and the physics is that the fire originated on the structure's exterior and entered through the window of bedroom #4. This is further explored with the CFD modeling in Section 5.2 of this report.

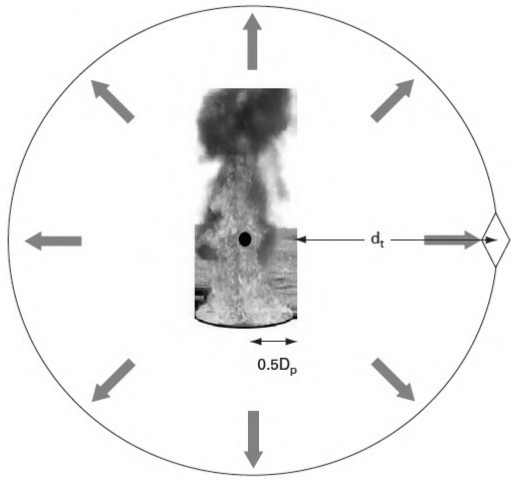

Figure 16: Diagram of flame radiation from a point source model

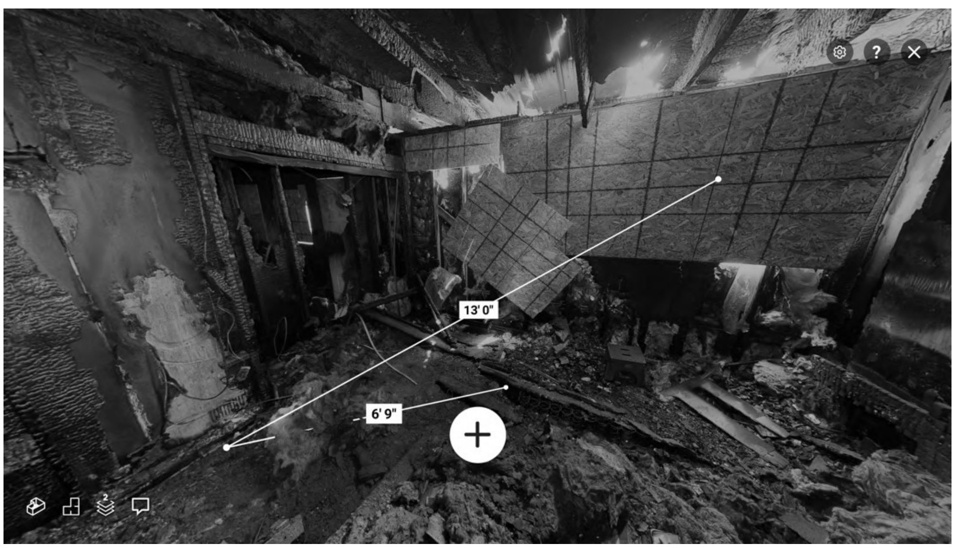

Figure 17: Matterport scan with dimensions from hoverboard location to the corner of the bunk bed (~6.75 ft) and the window (~13 ft).

5.2 Computational Fluid Dynamics / Fire Dynamics Simulator Simulations

The simulations illustrate the governing physics in a 3D animation program (Smokeview), allowing users to demonstrate temperature changes, heat transfer, fluid dynamics, and flaming combustion regions. A few of these graphic methods are used in the animations to serve as snapshots in time to better illustrate the locations of flaming combustion, fluid flows of heated

gases and airflow, tenability criteria, and locations and magnitudes of heat transfer and temperatures.

Graphic methods to illustrate aspects of the model used in this report include slice files and boundary conditions. A color scale is provided for each technique to reflect the actual values simulated by FDS. The second graphic method used is a 3D structure illustrating locations of flaming combustion visually by simulating flames accomplished through FDS, mathematically calculating combustion chemistry throughout the simulations (Figures 19, 23). The final graphic method used is the change of color to the lining surfaces (i.e., walls, contents) throughout the structure to display greater heat fluxes and temperatures (Figures 20-21, 24-26). A color scale is included with each image to identify the actual physical values simulated by FDS. Representative samples from the simulations have been provided below; however, all the data that supports the conclusions here will be provided electronically as part of the complete expert case file.

5.2.1 Simulations 2-4: Geometry Setup for Storage/Smoker's Shed Fire

Simulations titled Wadsworth_2-Wadsworth_4 were simulated as a single origin involving the storage shed along the east exterior wall of the structure. To collect additional data, additional thermocouples, slices, and devices were added to each successive simulation. The mesh resolution was evaluated and refined. The purpose of these simulations was to ensure that the geometry of the structure and initial setup were correct.

5.2.2 Simulations 5-8: Geometry Setup for Bedroom #4 Fire

The simulations titled Wadsworth_5-Wadsworth_8 were simulated as a single origin involving the hoverboard along the north wall of Bedroom #4. To collect additional data, additional thermocouples, slices, and devices were added to each successive simulation. The mesh resolution was evaluated and refined. The purpose of these simulations was to ensure that the geometry of the structure and initial setup were correct.

5.2.3 Hoverboard in Bedroom #4 Origin

More than 25 simulations were conducted to evaluate a single origin involving the hoverboard along the north wall of Bedroom #4 (See computer fire modeling notes.xlsx in the expert file).

This section summarizes the governing physics of a fire originating at the hoverboard in bedroom #4.

A fire originating at the hoverboard location in bedroom #4 results in fast smoke alarm activation (~5-6 seconds). The activation of the smoke alarm, regardless of the smoke detection algorithm or the associated variables, would be before the ignition of the bunk bed, the ignition of the wall behind the bunk bed, or the failure of the window. Therefore, had the fire originated within bedroom #4, the smoke alarm would have been activated early in the fire progression, which is inconsistent with the statements made by Gunner, Layne, and Kamille. Kamille testified that the smoke alarm awakened her, which would have only been after Gunner was awakened to the window gone from bedroom #4, as she also heard Layne and Gunner yelling for her.

The bunk bed would ignite before the window behind it failed. The window may fail when a fire originates at the hoverboard, but this is caused by the ignition and burning of the bunk bed near the window or when the compartment transitions through flashover. This is contradictory to Gunner and Layne's witness statements and their survivability. Neither Gunner nor Layne indicated that the bunk bed or bedding was ignited when they were awakened to the fire.

A fire originating at the hoverboard quickly creates temperatures above the tenability criteria for bedroom #4 doorway to the hallway. The temperature criteria were exceeded at the bedroom doorway for both the 6 ft and 3 ft heights within 5-49 seconds. See Figure 18 as a representative example of the temperature data for a thermocouple tree (temperatures at 1-ft intervals from the floor) in the bedroom doorway for bedroom #4. The temperature criteria are reached before the window fails, which is inconsistent with the witness statements and their survivability. Therefore, the egress of Layne and Gunner through the bedroom doorway with an origin at the hoverboard is inconsistent with their explanation of the events the night of the fire and the survivability of the occupants.

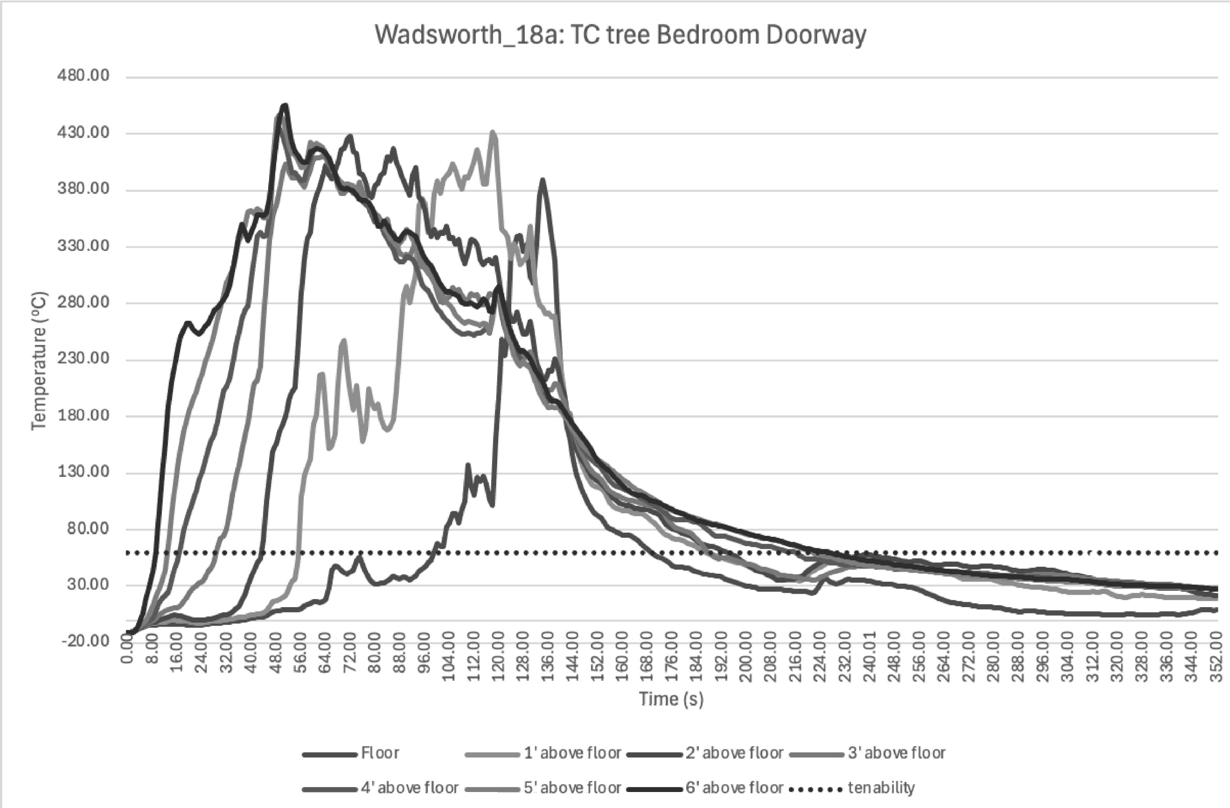

Figure 18: Thermocouple (TC) tree at the doorway to bedroom #4 (source: Wadsworth_18a)

Most of the flaming combustion remains near the hoverboard in the early stages of the fire until flames spread across the wood paneling lining the wall near the hoverboard and then across the compartment through radiant heat transfer, igniting the bunk bed. When the compartment nears full-room involvement and the window has failed, a flow path extends from the window to the open doorway of bedroom #4 (Figure 19). The ventilation-controlled conditions create a path along the north wall where combustion continues post-flashover. Therefore, the extent of damage along the north wall is consistent with ventilation-generated fire patterns along the flow path from the window to the bedroom doorway (Figures 19-21). The damage and fire patterns identified by the fire investigators near the hoverboard result from this flow path from the window to the doorway and are consistent with ventilation-generated fire patterns, not an origin at the hoverboard.

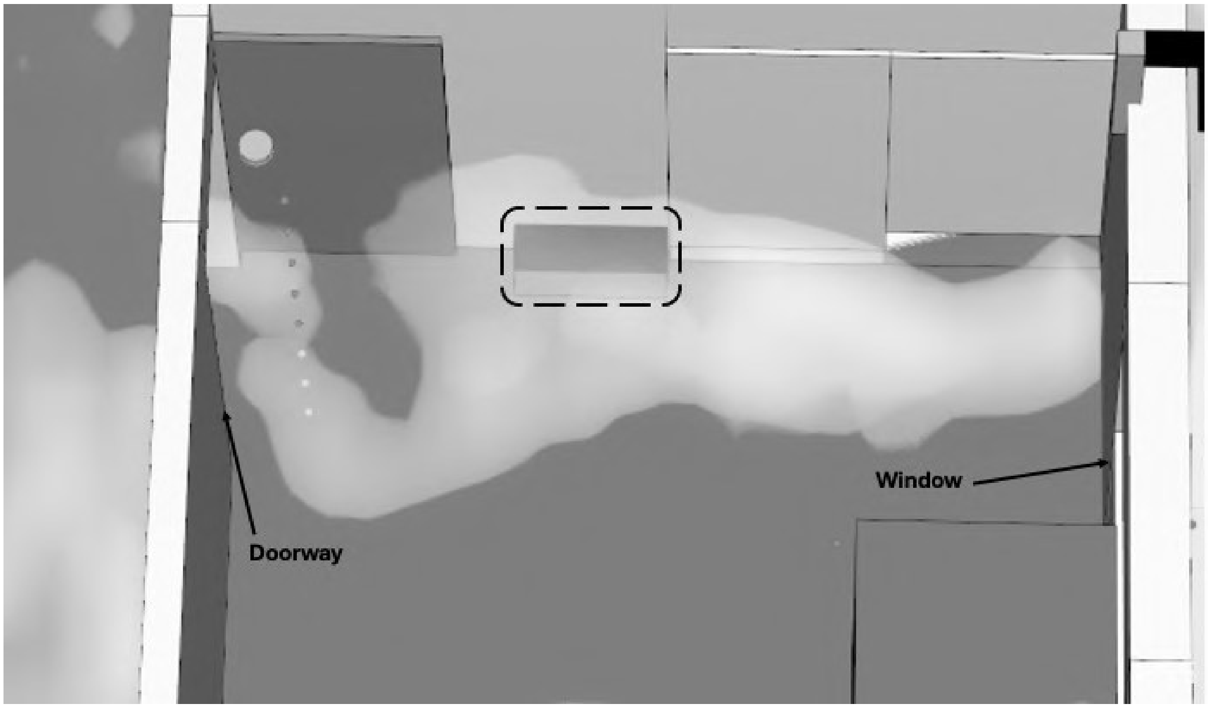

Figure 19: Hoverboard Origin: Bedroom #4 aerial view-location of mixture for flaming combustion within the compartment post-flashover (Note: dashed line is where the hoverboard was located; 130 seconds into the simulation (source: Wadsworth_16))

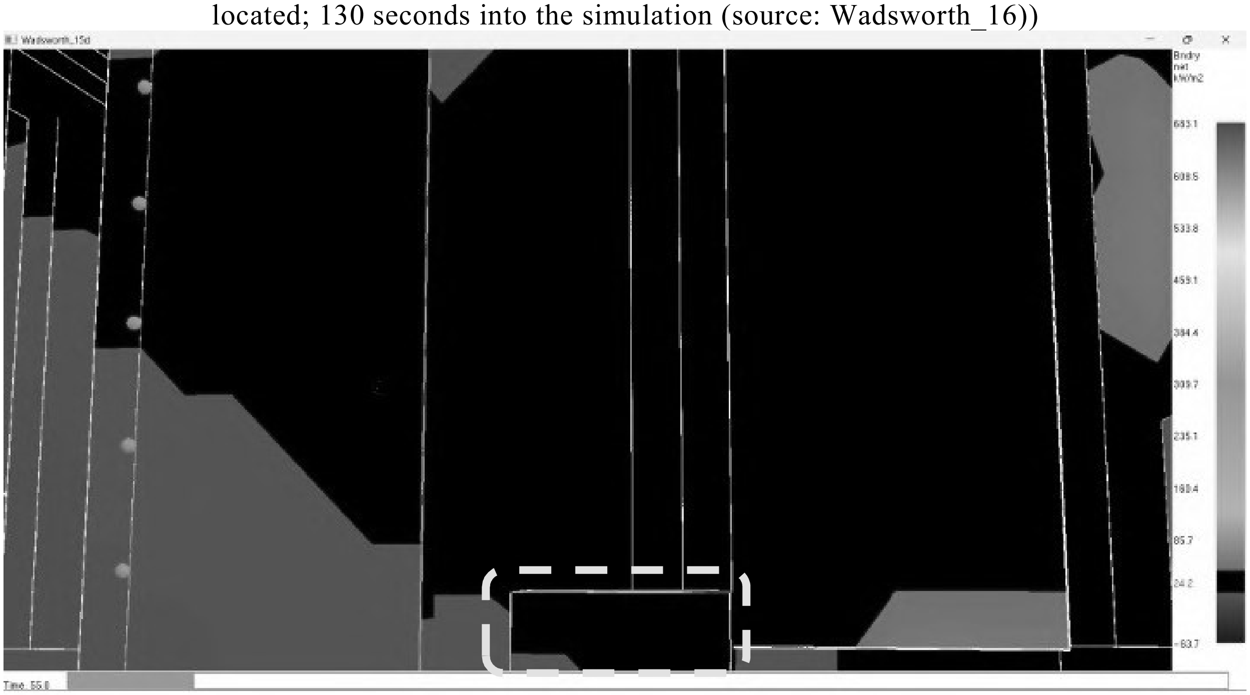

Figure 20: Hoverboard Origin: Heat Flux Boundary Condition in bedroom #4 looking at the north wall (note: dashed line is where the hoverboard was located (source: Wadsworth_15d))

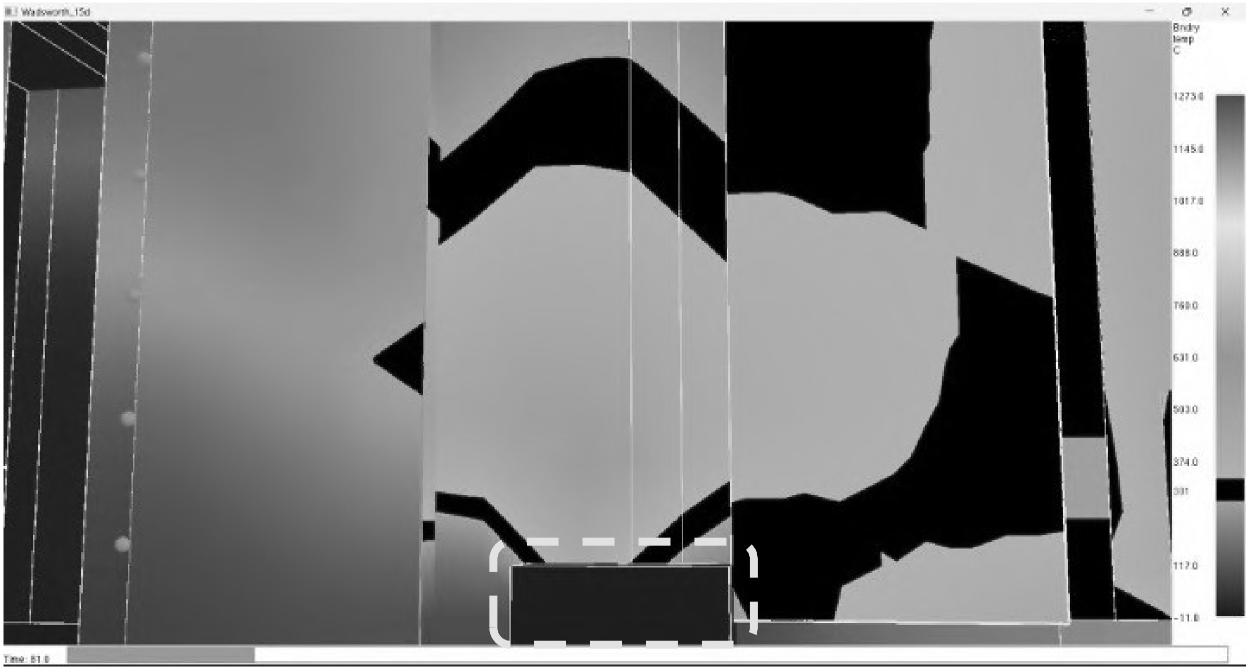

Figure 21: Hoverboard Origin: Wall Temperature Boundary Condition in bedroom #4 looking at the north wall (note: dashed line is where the hoverboard was located (source: Wadsworth_15d))

5.2.4 Fire Originating in Storage "Smoker's" Shed

More than 20 simulations were conducted to evaluate a single origin involving the exterior storage "smoker's" shed near bedroom #4 window (See computer fire modeling notes.xlsx in the expert file).

Smoke alarm activation occurs quickly after the window fails (~10-15s after window failure). The failure of the window, followed by the smoke alarm activation, is consistent with the witness statements of Gunner and Kamille.

Following the window's failure, the bunk bed ignites relatively quickly. The wood paneling along the window wall also ignites, producing enough energy to cause bedroom #4 to transition through flashover into full-room involvement. The ignition and burning of the fuels along the window wall following the window's failure are consistent with the witness statements.

The tenability threshold for gas species (fractional effective dose) within bedroom #4 is reached 4-5.5 minutes later in the storage "smoker's" shed origin than at the hoverboard origin. The storage "smoker's" shed origin is more consistent with the children's safe egress from the structure.

The doorway temperature tenability thresholds are met as bedroom #4 transitions to full-room involvement, which only occurs after the window failure and the fire spreads into bedroom #4. See Figure 21 as a representative example of the temperature data for a thermocouple tree (temperatures at 1-ft intervals from the floor) in the bedroom doorway for bedroom #4.

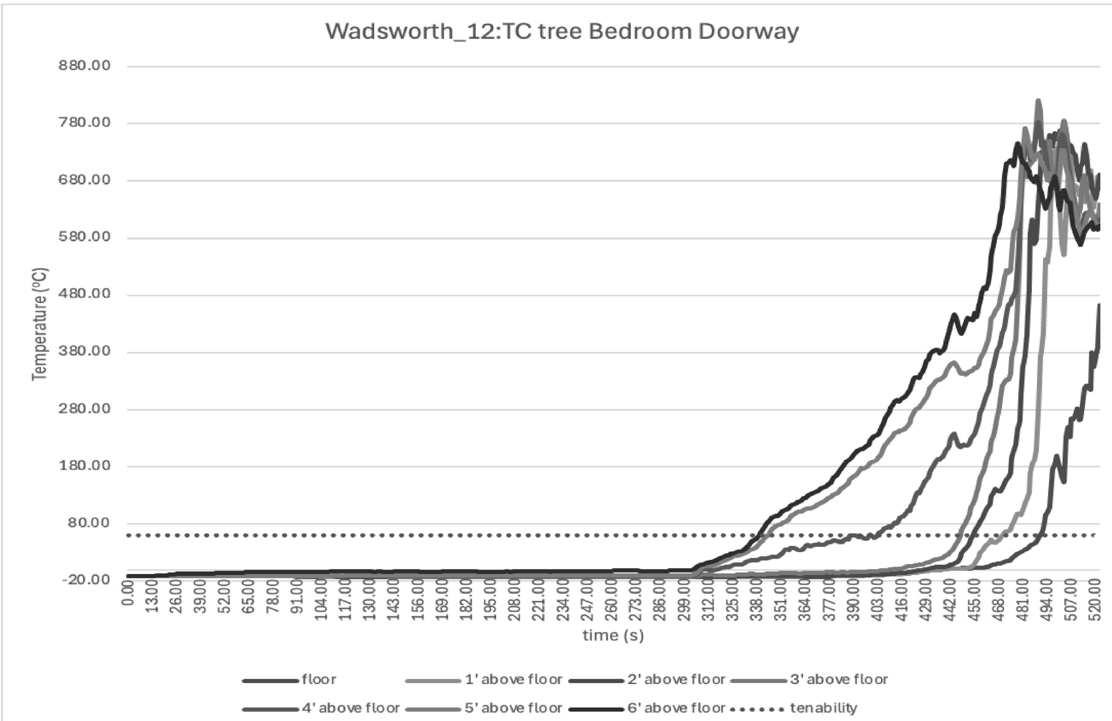

Figure 22: Thermocouple (TC) tree at the doorway to bedroom #4 (source: Wadsworth_12)

Following the failure of the window and ignition of the bunk bed, most of the combustion remains near the bunk bed and spreads across the compartment through radiant heat transfer and fire spread across the wood paneling. When the compartment nears full room involvement, a flow path extends from the window to the open doorway of bedroom #4 (Figures 23-26). The ventilation-controlled conditions within bedroom #4 create a path along the north wall where combustion continues post-flashover. Therefore, the extent of damage along the north wall is consistent with ventilation-generated fire patterns along the flow path from the window to the bedroom doorway and not an area of origin (Figures 23-26).

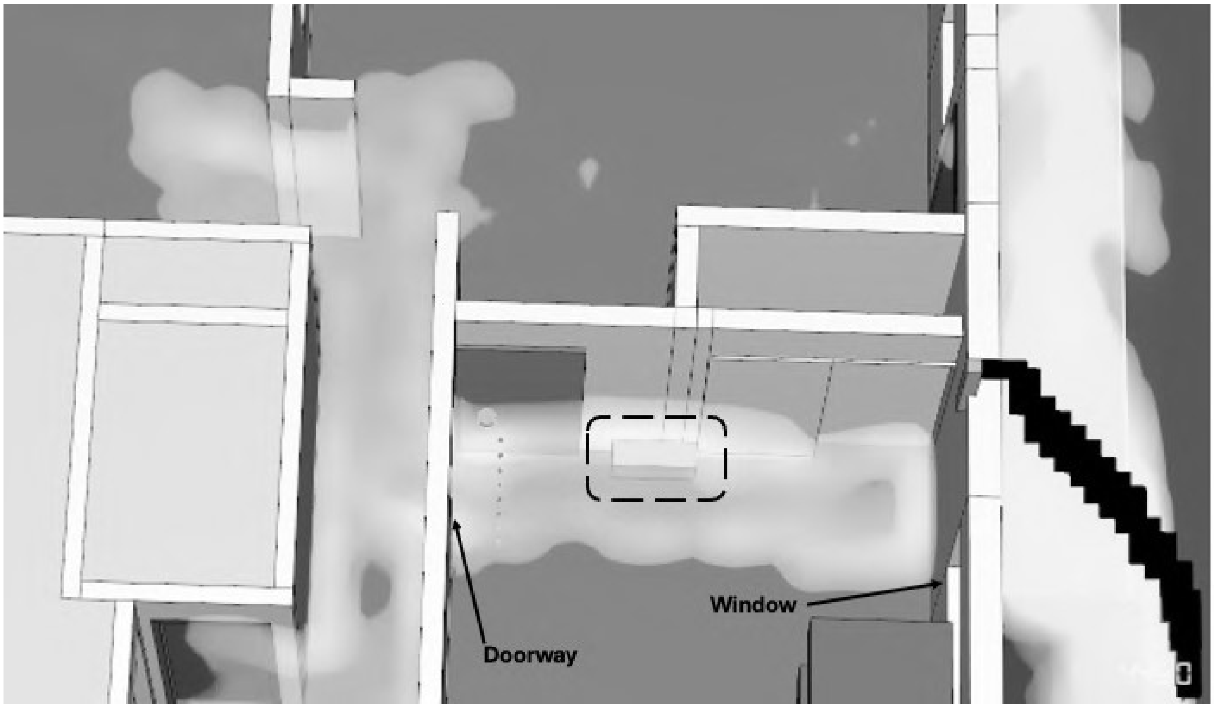

Figure 23: Storage "Smoker's" Shed Origin: Bedroom #4 aerial view-location of mixture for flaming combustion within the compartment post-flashover (Note: dashed line is where the hoverboard was located; 446 seconds into the simulation (source: Wadsworth_12a))

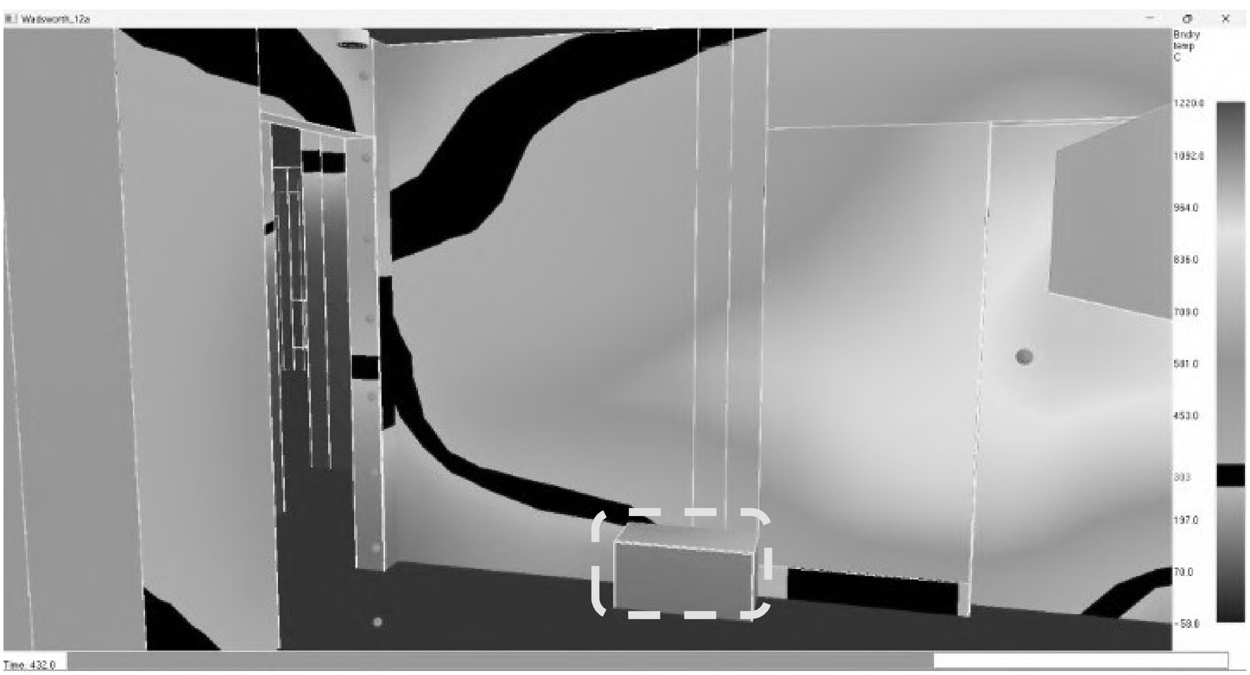

Figure 24: Storage "Smoker's" Shed Origin: Wall Temperature Boundary Condition in bedroom #4 looking at the north wall (note: dashed line is where the hoverboard was located (source: Wadsworth_12a))

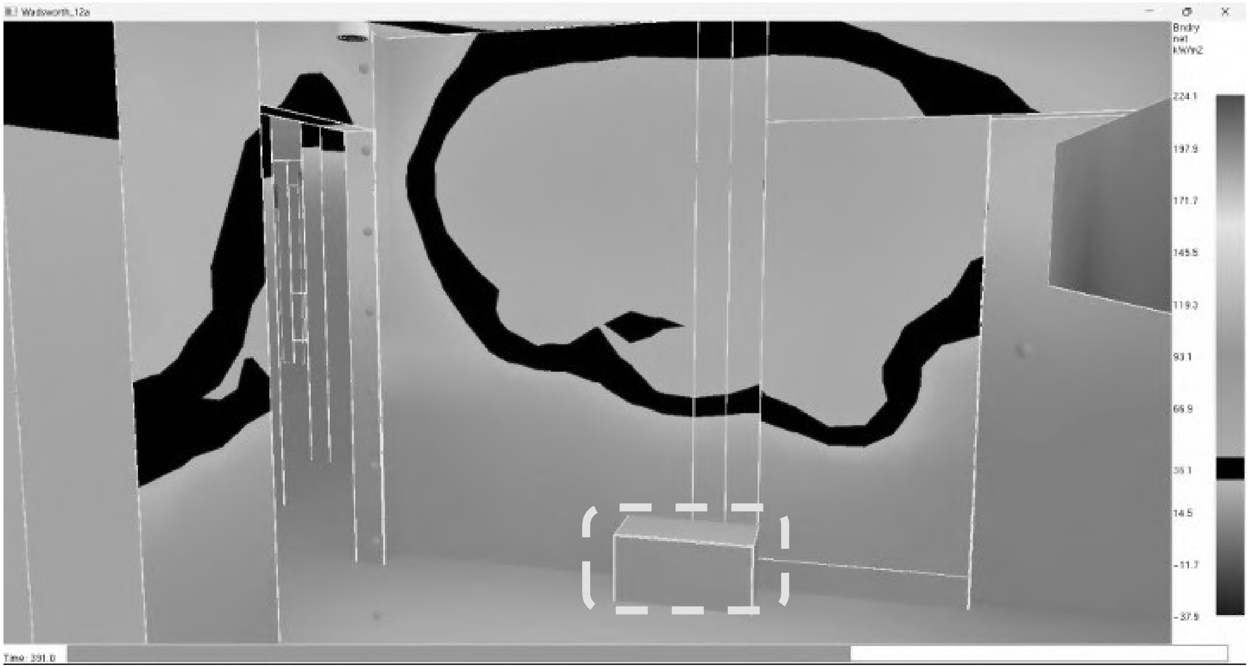

Figure 25: Storage "Smoker's" Shed Origin: Heat Flux Boundary Condition in bedroom #4 looking at the north wall (note: 391 seconds into the simulation; dashed line is where the hoverboard was located (source: Wadsworth_12a))

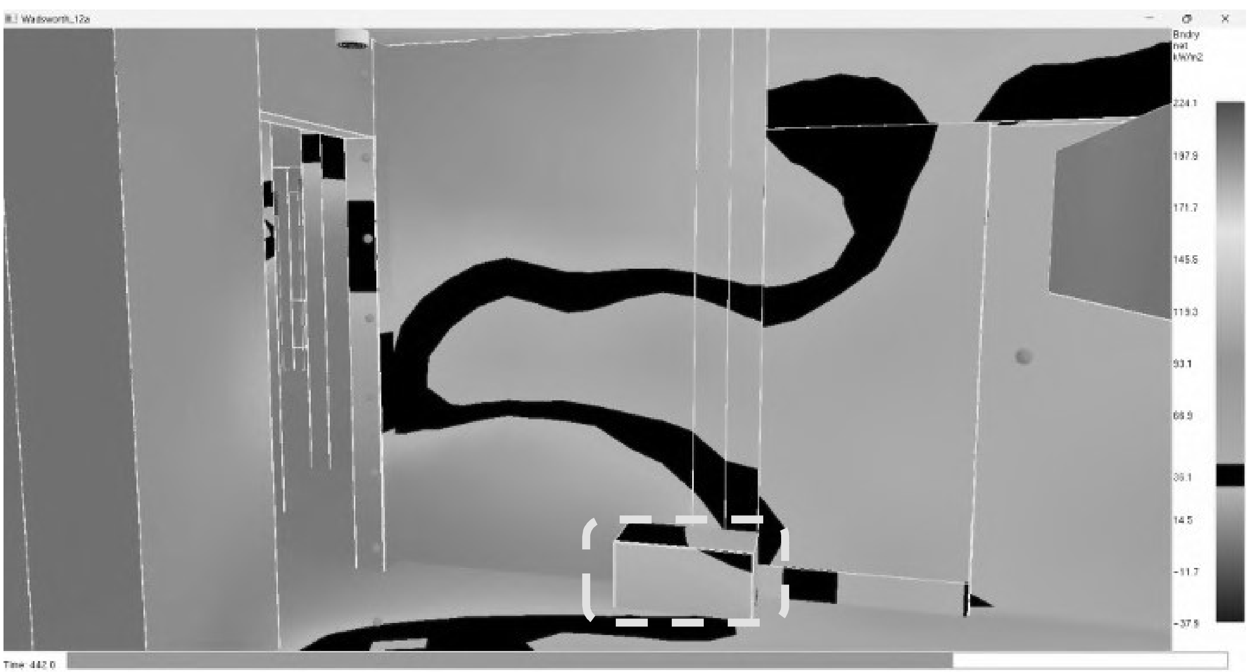

Figure 26: Storage "Smoker's" Shed Origin: Heat Flux Boundary Condition in bedroom #4 looking at the north wall (note: 442 seconds into the simulation; dashed line is where the hoverboard was located (source: Wadsworth_12a))

6.0 Conclusions

The analysis of the fire dynamics for this scenario is consistent with a fire originating on the structure's exterior at the storage "smoker's" shed. In summary, the fire testing, empirical correlations, CFD simulations, and the application of fundamental fire dynamics verify that a single origin at the exterior storage "smoker's" shed better replicated the fire damage in the structure and better correlated to the witness statements and timeline. The hoverboard origin theory does not accurately reflect the witness statements or the physical evidence after the fire, violating fundamental laws of physics. These conclusions are supported by the following:

1. The witness statements by the children consistently indicate the window behind the bunk bed had failed before the ignition of the bunk bed or anything else in the room. It is physically impossible for a fire that originates at the hoverboard to ignite the wall behind the bunk bed and fail the window without igniting the bunk bed and bedding and not to cause significant pain and injuries to the children sleeping on the bunk bed. A fire at the hoverboard would have ignited the bunk bed, ignited bedding materials, and began injuring the children before causing the window to fail. The conclusion that the hoverboard was the area of origin violates the laws of physics.
2. The description of flames and an orange glow only witnessed across bedroom #4 at the bunk bed and along the east wall is inconsistent with the fire dynamics of a fire originating at the hoverboard near the doorway of bedroom #4. A fire originating on the exterior and spreading into the structure through bedroom #4's window is consistent with the witness statements.
3. A fire at the hoverboard would have quickly blocked egress through bedroom #4's doorway. Temperatures above the tenability criteria for the doorway to the hallway from bedroom #4 would be swiftly reached had a fire originated at the hoverboard. Given the fuels present in the bedroom, the timing to transition bedroom #4 through flashover would have been very fast and quickly created untenable conditions within the bedroom. This is inconsistent with the witness statements, movement of the children through the house, and survivability of the children from bedroom #4. However, a fire along the structure's exterior corroborates the children's witness statements, timing, and survivability.
4. The activation of a smoke alarm within the house after the window had failed, as described by Gunner Wadsworth and Kamille Wadsworth, is inconsistent with a fire originating

within bedroom #4. However, this sequence of events is consistent with a fire on the structure's exterior spreading into bedroom #4 through the window.

5. Stephanie Wadsworth attempted to escape through the rear pedestrian door on the morning of the fire; however, when she opened the door, her egress was blocked by flames already along the structure's exterior. Had the fire originated in bedroom #4 at the hoverboard, the storage shed would have only ignited after the window failed and bedroom #4 had transitioned through flashover. This is inconsistent with the flames witnessed on the structure's exterior that blocked egress, yet conditions inside the house were still tenable for the children and Stephanie at that time.
6. The storage “smoker’s” shed had already lost most of its mass due to combustion when Mr. Ryan Pasborg arrived at the house on the morning of the fire. He testified that upon arrival, he did not see a shed but could see flames extending out of the window to bedroom #4 and flames along the ground approximately calf-high. This is consistent with the shed being wholly melted and most of its mass consumed by combustion before his arrival. This is inconsistent with the conditions in the house, which were still tenable when he entered to find Weston and Stephanie.
7. An exemplar storage shed burns with a high heat release rate, producing flame heights greater than 20 feet. The energy released from the storage shed would be sufficient to create conditions similar to the fire development identified by witnesses to the fire.
8. The location and magnitude of damage along the north wall behind the hoverboard in bedroom #4 were created during ventilation-controlled conditions within the bedroom. The ventilation-generated fire patterns along the north wall are consistent with damage created during a post-flashover compartment fire.[72] CFD modeling confirmed that regardless of whether the fire originated on the structure's exterior or at the hoverboard, the location and magnitude of damage along the north wall are consistent with ventilation-generated fire patterns.[73] The damage near the hoverboard location is inconsistent with origin patterns from the hoverboard.

[72] NFPA 921 (2024), Section 6.4.2
[73] Ibid, Section 6.4.2.7

Mr. Michael Schulz and Mr. Derek King's conclusions and opinions regarding the origin and cause of this fire were not performed using the scientific method, violate the laws of physics, are not generally accepted within the profession, and have reached beyond the scientific stage of verifiable certainty for the procedures and techniques employed during their investigation. Therefore, their opinions are scientifically unreliable, do not follow the guidelines of NFPA 921, and are wrong.

This completes the initial review and analysis of the above-noted matter. Additional information concerning this matter may influence the opinions expressed. If additional information becomes available, please forward for my review and consideration. If you have any further questions, please get in touch with me.

Respectfully,
FIRE Dynamics Analysts, LLC

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Owner / Sr. Fire and Explosion Analyst

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Technical Reviewer

Attachments

Appendix A-Gregory E. Gorbett CV

Appendix A – Gregory E. Gorbett CV